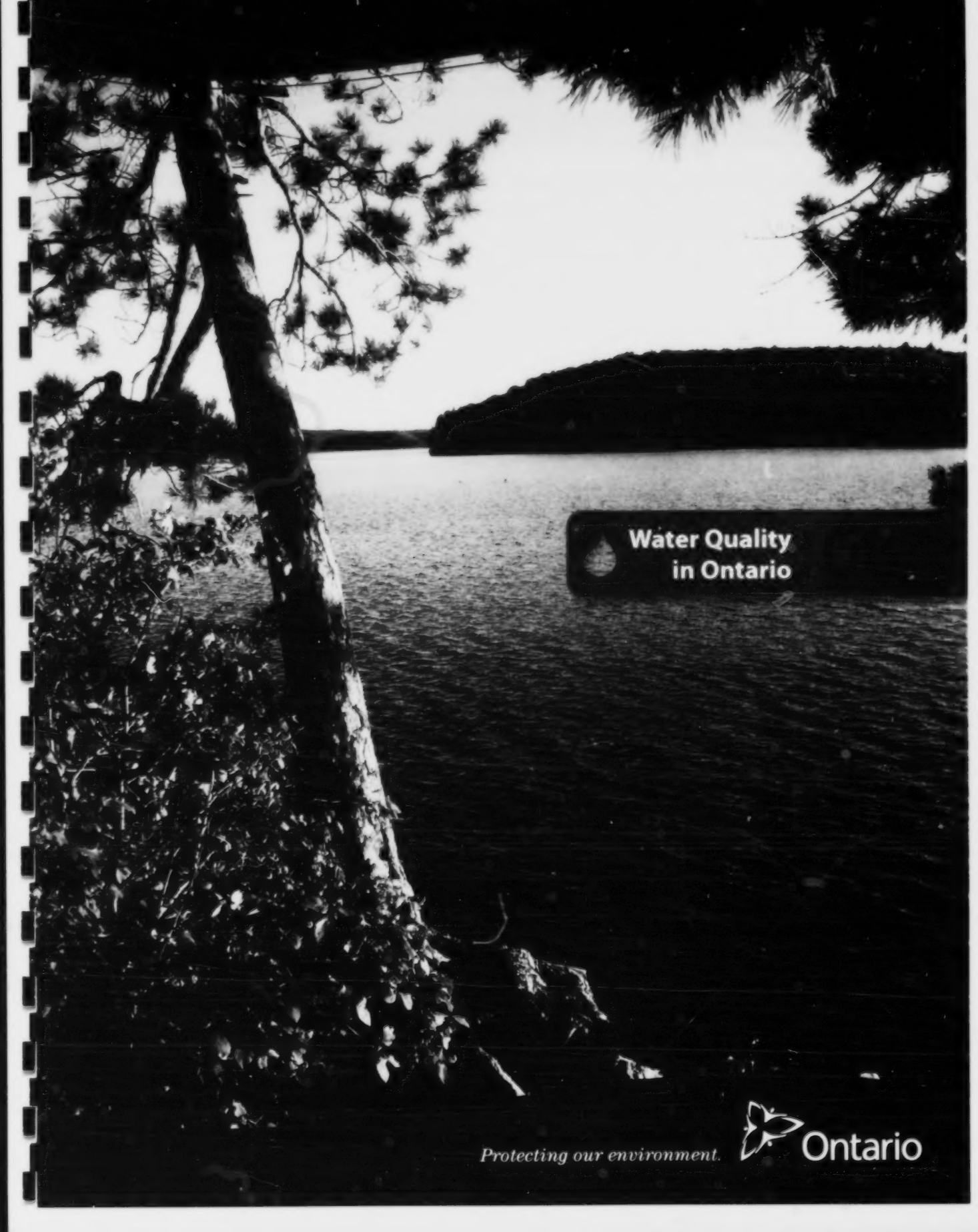
Water Quality
in Ontario
Protecting our environment.
Ontario

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Introduction

Clean water is essential. We are very lucky in Ontario. Our province borders on four of the five Great Lakes and we have more than a quarter of a million lakes, rivers and streams. These water resources are the cornerstone of the quality of life that we enjoy in Ontario. Our health, the health of the environment and our economic prosperity depend on them. This is why the Ontario government is working hard to make our water among the best protected in the world.

The Ontario government has put in place some of the most rigorous water protection measures in North America. The *Safeguarding and Sustaining Ontario's Water Act* strengthens protection and conservation of the Great Lakes and all Ontario's water resources, including a stronger ban on water diversions from the Great Lakes Basin. The *Lake Simcoe Protection Act* will restore and protect the health of this threatened lake. Water taking rules have been strengthened. Ontario has made great strides in protecting the quality of our water resources and there is more to come. Work is underway on developing strategies to reduce toxics in our environment and for combating climate change.

The Ministry of the Environment monitors water quality in the Great Lakes and in lakes, rivers, streams, and groundwater across the province. Every year, the ministry collects and analyzes tens of thousands of samples from water, sediment, and aquatic life such as fish and algae. This extensive monitoring helps us understand the state of our water resources, the impacts of our activities and the causes of problems, and to identify emerging problems. Ontario's monitoring network is showing us how climate change is affecting our water resources. For example, warmer temperatures have lengthened the ice-free season in Lake of the Woods. The scientific information we get from monitoring helps us develop new protection measures, and to track and report on our progress.

Monitoring is telling us that we have made progress but that we need to do more. Levels of polychlorinated biphenyls (PCBs) and mercury are decreasing in our Great Lakes; phosphorus inputs to Lake Simcoe are lower; and northern lakes are showing signs of recovering from acid rain. In many lakes and streams, however, phosphorus levels are still elevated and sport fish are still not completely safe to eat. Emissions that cause acid rain must be further reduced to ensure the continued recovery of lakes.

This first *Water Quality in Ontario Report* presents findings on current water quality issues familiar to people in Ontario. Topics covered include elevated nutrients such as phosphorus, toxic substances, acid rain, and climate change. The results of our monitoring work show that the actions we have taken to date to improve water quality have been successful, but also that continued vigilance is needed. Monitoring and the valuable knowledge it gives us play a very important part in what the government is doing to protect water quality in Ontario now and in the future.

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1.0 Ontario: Land of Water

The Ontario landscape: rich in water resources

Water quality in Ontario is affected by the geological landscape and Ontario's geology has shaped its regional land use patterns and water quality conditions. Ontario can be subdivided into two broad geological regions: the older, rugged, erosion-resistant rocks of the Canadian Shield, and the younger, relatively flat-lying rocks of the Borderlands, which include the Hudson Bay Lowlands in northern Ontario and the St. Lawrence Lowlands in southern Ontario. Maps of land use and geology are shown in Figures 1.1 and 1.2, respectively.

Ontario has:

- more than 250,000 inland lakes;
- over 500,000 kilometres of rivers and streams; and,
- 5,300 kilometres of shoreline on four of the five Great Lakes.

The Canadian Shield, which makes up two-thirds of the land area in Ontario, is characterized by thin soils and ancient bedrock. The Shield was covered with glaciers during the last ice age, and the ice scraped away most of the soils and carved out tens of thousands of lake basins. The Shield is dominated by lakes, wetlands, bedrock outcrops and forests, and is largely unsuitable for agriculture. It is mostly undeveloped, but recreational properties line the shores of many lakes. The Shield is also a rich source of metallic minerals and timber, and a few urban areas have developed around the mining and forest industries.

Drainage is generally poor on the Shield, and wetlands are abundant.

Did you know?

The word *Ontario* is believed to be derived from the Iroquoian word "Kanadario" or its variations, "Onitariio" and "Skanadario," all of which mean "sparkling, pretty or beautiful water or lake."

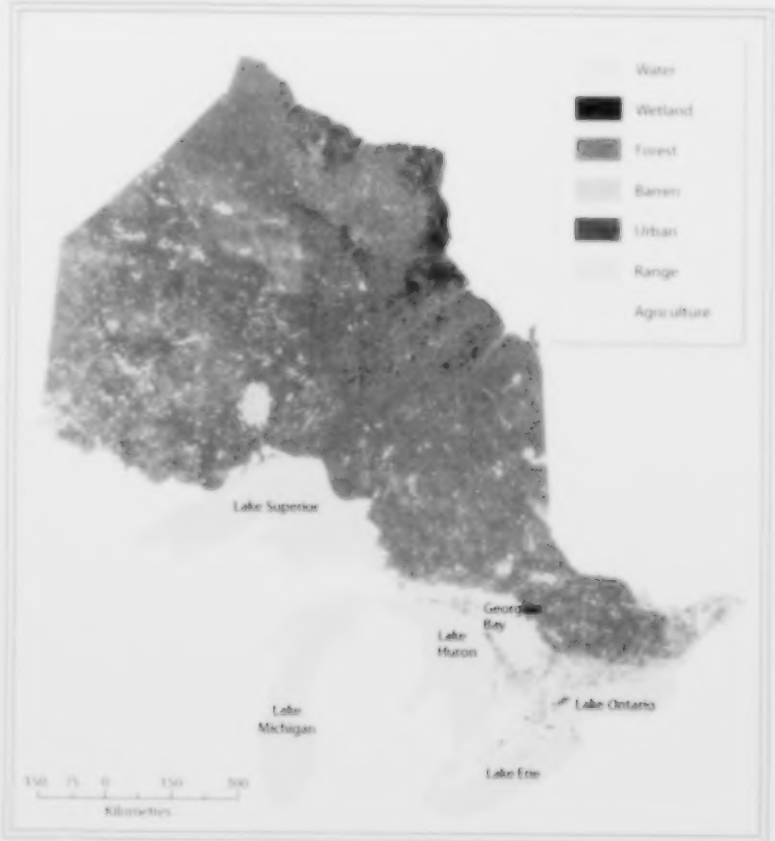


Figure 1.1 Land cover of Ontario

The decomposition of organic matter in wetlands releases dissolved organic carbon that contributes to the natural tea colour that is characteristic of surface waters on the Shield. Wetlands influence the acidity of surface waters because they store and release sulphate and naturally occurring organic acids. Lakes and streams on the Shield are particularly sensitive to acid deposition or acid rain. The thin soils and soft waters of the Shield have limited capacity to neutralize acids. Surface waters on the Shield are also sensitive to nutrient enrichment (excessive nutrients in the water, especially phosphorus, caused by human activities) since background levels of phosphorus and nitrogen are generally low.

The Borderlands are comprised of younger and more easily eroded sedimentary rocks. The Niagara Escarpment, which extends from the Niagara River to the Bruce Peninsula and Manitoulin Island, is a prominent example of the sedimentary rock of the Borderlands.

In northern Ontario, the Hudson Bay Lowlands extend from the Shield north to the shores of Hudson Bay and James Bay. The region is poorly drained and dominated by wetlands. It is sparsely populated with small settlements along the shores of Hudson Bay.

Figure 1.2 Geology of Ontario

In southern Ontario, the St. Lawrence Lowlands extend from the Shield south to the Great Lakes and the St. Lawrence River. This region is covered by thick soil and rock deposits on the surface of the earth (called overburden), which were left behind at the end of the last ice age. A prominent example is the Oak Ridges Moraine, which extends from the Niagara Escarpment to the Trent River, separating the streams of the Lake Ontario drainage basin from those that flow into Georgian Bay and the Trent River.

The deep, nutrient-rich soils of southern Ontario are a striking contrast to the thin soils of the Canadian Shield. Much of the agricultural land in the province is in the St. Lawrence Lowlands. The region also supports the majority of Ontario's population of 12 million people. The largest concentration of people and cities is in the Golden Horseshoe along the western end of Lake Ontario.

The dissolution of the sedimentary bedrock in the St. Lawrence Lowlands results in ground and surface waters rich in calcium and other hardness ions. The region is more resistant to the impacts of acid rain, in comparison to the softer waters of the Canadian Shield. However, the agricultural and urban land uses that dominate the region have resulted in a range of water quality issues, from nutrient enrichment to the release of toxic substances.

Water quality monitoring involves collecting and analyzing water quality indicators to detect and describe ecosystem change and environmental quality. This report presents results from the ministry's water quality monitoring programs for lakes, streams and groundwater.

Ontario's geology has shaped its regional land use patterns and water quality conditions.

2.0 Water Quality Monitoring

Why is water quality monitoring necessary?

Water quality monitoring provides a direct measure of success to determine if investments and efforts by governments, industry and individuals are working to protect water quality in Ontario. The ministry's ambient monitoring programs track the overall conditions in the environment, and provide basic information on the quality of water resources across the province. Ontarians need this information to understand the state of the environment, the impacts of their activities and the progress that is being made to protect water resources. The information gained from monitoring helps with prioritizing the issues to be addressed and choosing the geographic areas in which to concentrate, thus helping to ensure effective management of water resources.

Innovative strategies are used to measure pollution levels in surface water.

The numbers: The scope of monitoring

The statistics for the 2006 calendar year demonstrate the scope and extent of the ministry's investments in ambient water quality monitoring programs.

- 5,600 = number of locations across Ontario where samples were collected.
- 30,300 = number of samples that were collected and analyzed, comprising:
  - 21,500 samples of water;
  - 200 samples of sediment; and,
  - 8,600 samples of fish, benthic invertebrates and plankton.
- 600,000 = number of individual pieces of data on the status of water quality in Ontario that resulted from this sampling.

Ministry scientists retrieve a semi-permeable membrane device from the Great Lakes. The device helps to measure chemical contaminants in surface water.

The ministry monitors indicators of fundamental processes in aquatic ecosystems. These are used to relate human activities to water quality. Observations of trends and patterns in these indicators support the early identification of new and emerging environmental problems. This information is necessary so that the government can develop policies and regulations to protect our water resources.

Ministry of the Environment responsibility for water quality monitoring

The ministry's Environmental Monitoring and Reporting Branch leads the operation of provincial-scale programs to monitor surface and groundwater quality across Ontario. Information on these monitoring programs can be found in Appendix A.

The ministry's water monitoring activities are integrated with the sample analysis done at the Laboratory Services Branch. From basic water quality parameters such as pH and turbidity to metals such as mercury and lead, organic compounds including PCBs and pesticides, and microbiological organisms, the ministry's laboratory analyzes tens of thousands of water samples each year for hundreds of possible pollutants. Analytical methods are continuously evolving to enable the detection and monitoring of pollutants of emerging concern such as pharmaceuticals and flame retardants.

How do we measure water quality?

The ministry collects and analyzes tens of thousands of samples of water, sediment and aquatic life each year. The types of samples that are collected, and the ways in which the samples are analyzed, vary with the objectives of the monitoring. In fact, monitoring objectives influence all aspects of the design of

Sediment sampling in the Great Lakes.

The ministry's Environmental Monitoring and Reporting Branch leads the operation of provincial-scale programs to monitor surface and groundwater quality across Ontario.

water quality monitoring programs from the duration, frequency, timing and location of sample collections to data analysis, interpretation and reporting. The ministry's monitoring programs include the chemical analysis of water, sediment and tissue and the biological analysis of aquatic communities. Additional innovative sampling strategies are also used in situations where conventional approaches are insufficient.

Water chemistry

Water samples from streams, lakes and groundwater aquifers are collected and analyzed in the laboratory for various indicators. The indicators that are monitored are chosen to be consistent with the information objectives. For example, phosphorus and nitrogen levels are monitored in Ontario's lakes and streams to assess the impacts of nutrient sources and the potential for excessive plant growth and algae blooms. Water chemistry monitoring results are compared to water quality criteria to assess impacts on the health and diversity of aquatic plants and animals and to determine if beneficial human uses of water resources are protected.

Some measurements of the physical and chemical properties of water are made in the field using portable sensors. Water temperature is an easily measured indicator that has considerable chemical and biological significance. A secchi disk is used to measure the clarity of lakes, a surrogate indicator of the abundance of algae. Some sensors measure turbidity, dissolved oxygen, pH and conductivity. Conductivity is correlated with chloride concentrations, which in turn are an indication of the impacts of the addition of salt in the environment.

Volunteers in the ministry's Lake Partner Program measure lake water clarity and collect water samples for phosphorus analysis.

Sediment and tissue

Effective water quality monitoring requires more than the collection and analysis of water samples. Some metals, trace organic substances and other contaminants are relatively insoluble in water. They tend to adsorb to sediment particles and settle to the bottom of streams and rivers or accumulate in biological tissues. In many cases it is more effective to measure sediment and tissue chemistry rather than water chemistry to track contaminant levels in the environment.

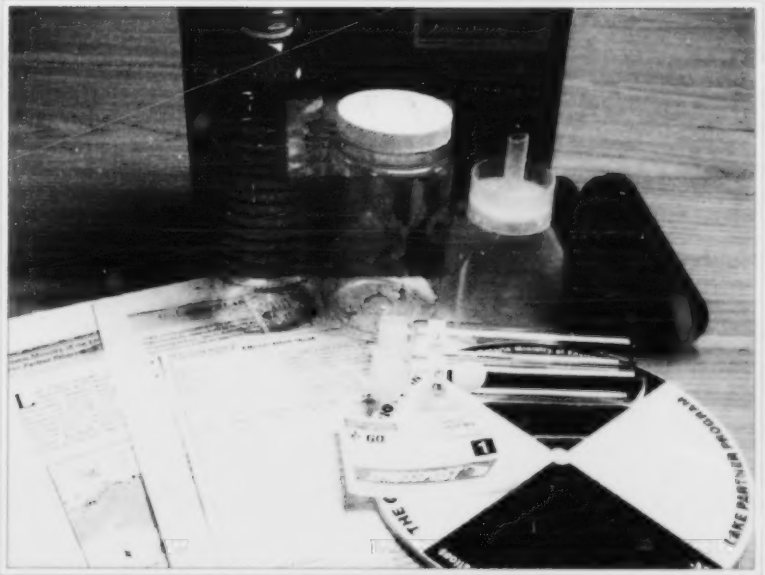
The ministry collects sediment samples from the Great Lakes, inland lakes and streams. These samples are analyzed in the laboratory and the results are compared to sediment quality criteria developed to protect aquatic life and prevent the accumulation of toxic substances in aquatic food webs. Sediment cores are also collected to assess long-term changes in the chemistry and biology of a lake.

Trace metals and organic contaminants such as PCBs and organochlorine pesticides are persistent in the environment and have the potential to bioaccumulate through the food web into fish and subsequently fish-eating birds and mammals. Tissue samples from fish are collected and analyzed in the ministry's laboratory for a variety of substances. Results are compared to human health guidelines to provide consumption advice for sport fish.

Aquatic life

In addition to the chemical analysis of water, sediment and tissues samples, aquatic organisms are used as indicators of water quality. Benthic invertebrates, algae, plankton and fish are sensitive to changes in their physical and chemical habitat. For example, increasing amounts of algae are often correlated with higher concentrations of nutrients like phosphorus. Measuring the diversity and abundance of aquatic organisms can tell us a lot about the overall health of a lake or stream. A diverse community made up of species that are sensitive to pollution indicates good water quality. Conversely, a community that is dominated by a few species that are tolerant of pollution can indicate degraded water

Sport fish are collected in partnership with the Ontario Ministry of Natural Resources.



Partners in the Lake Partner Program are provided with a kit containing water sampling equipment and forms for recording their field measurements.

Measuring the **diversity and abundance of aquatic organisms** can tell us a lot about the **overall health** of a lake or stream.

Benthic invertebrates, such as the mayfly nymph pictured here (approximately 1 cm long), are good indicators of water quality.

quality. The ministry's biomonitoring programs compare biological communities at different locations to assess the relative status of aquatic ecosystems.

Additional sampling strategies

In selected circumstances, innovative monitoring strategies are required to enhance the collection of the data to address a challenging monitoring objective. For example, passive sampling strategies including semi-permeable membrane devices (SPMDs) are used to measure levels of organic contaminants. SPMDs are devices consisting of a plastic tube containing a chemical that accumulates contaminants. They integrate exposure to very low levels of contamination over time to help in identifying sources and assessing impacts on aquatic species. In another example, high-tech sensors are used to monitor water quality continuously in streams and the nearshore of the Great Lakes to measure the changes in water quality that occur with runoff from the landscape after a rainstorm.

Water quality monitoring partnerships

The success of the ministry's monitoring programs depends largely on the contributions of partners and volunteers. In fact, valuable monitoring data could not be collected on such a wide scale without the help of partners. Partners include individuals and organizations that share an interest in monitoring and protecting the quality of Ontario's water resources. They are specially trained to collect field observations and environmental samples according to standard protocols, to ensure that results are consistent and comparable across Ontario.

The ministry works closely with government partners such as the Ontario Ministry of Natural Resources (MNR) to collect sport fish from 1,700 locations across the province for the Sport Fish Contaminant Monitoring Program. The

ministry also works closely with Environment Canada to coordinate monitoring activities in the Great Lakes, under the Great Lakes Nearshore Monitoring and Assessment Program, and with municipalities to monitor drinking water sources as part of the Drinking Water Surveillance Program (DWSP).

Other partners are dedicated volunteers from the public and environmental organizations such as lake associations. The ministry's Lake Partner Program works with approximately 800 volunteers from across Ontario to measure water clarity and collect water samples for total phosphorus analysis.

Ontario's Benthos Biomonitoring Network (OBBN) monitors water quality in lake, stream and wetland ecosystems using these benthic invertebrates as indicators for over 700 sites. Partners include government organizations (e.g., national parks, Ontario provincial parks, and municipalities), colleges and universities, non-governmental organizations, and citizen-scientist volunteers.

Partners in the Ontario Benthos Biomonitoring Network participate in training workshops to learn the protocols for the collection and identification of benthic invertebrates.

The Provincial (Stream) Water Quality Monitoring Network (PWQMN) collects water quality information from rivers and streams across Ontario. The program has been operating successfully since 1964, based on the strength of partnerships. Currently, over 400 locations are being monitored in partnership with Ontario's Conservation Authorities, several municipalities, and an Ontario park.

The Provincial Groundwater Monitoring Network (PGMN) collects ambient groundwater quality and water level information from key aquifers across Ontario. The network works in partnership with Ontario's Conservation Authorities and municipalities (in areas not covered by a Conservation Authority).

Water quality in rivers and streams is measured in the Provincial (Stream) Water Quality Monitoring Network

Groundwater levels and quality are measured in the Provincial Groundwater Monitoring Network.

Part II

Introduction

Taking action to protect the Great Lakes and Lake Simcoe, reducing toxics and combating climate change are amongst the Ontario government's top environmental priorities. In this report we focus on phosphorus enrichment, acid rain, toxic substances and climate change since information on these issues is important to addressing the priorities. With the exception of the emerging issue of climate change, the ministry has been monitoring these issues for decades.

Programs initiated in the 1970s have reduced phosphorus levels in the Great Lakes and many streams and inland lakes. This work continues in the Lake Simcoe watershed with the passage of the *Lake Simcoe Protection Act* in 2008. Reducing the amount of phosphorus entering Lake Simcoe to 44 tonnes per year is a key part of the government's efforts to improve the health of the lake. The long term monitoring described in this report helped to set this target and will track our progress in restoring Lake Simcoe.

The *2007 Canada-Ontario Agreement Respecting the Great Lakes* (COA) commits the governments of Ontario and Canada to work together to restore and protect the Great Lakes watershed, which includes the rivers and streams that drain into the lakes. Reducing harmful pollutants and understanding and adapting to climate change are amongst the Ontario government's top priorities for the Great Lakes.

Efforts to control emissions of air pollutants that cause acid rain have been underway since the 1970s. Encouraging results from lakes in the Sudbury area show dramatic improvements in water quality following massive reductions in acid-causing emissions. However, acid rain remains a problem. Lakes in central and northern Ontario continue to be affected by acid rain despite the widely-held perception that the problem has been solved. More recently, scientists have noticed that amounts of acid-neutralizing calcium in watersheds are decreasing. It is also becoming increasingly evident that recovery of lakes from acidification is closely linked to the emerging issue of climate change. The case is not closed on acid rain. Ongoing studies like those outlined in this report continue to track long term progress toward environmental recovery. These studies continue to have local, provincial, national and international relevance as they form the basis for agreements that address the issue of air pollutants emitted in Ontario and the long-range transport of pollutants emitted in other provinces and countries.

Government regulations on industrial discharges dramatically reduced the amounts of toxic substances entering Ontario's environment. However, some substances persist in the environment due to their long-lived nature, their continued use in some products and processes and the difficulty of cleaning up contaminated areas. Some new substances which came into use as a replacement for banned substances, or for new applications, have been found in increasing concentrations. Continued vigilance is needed to control the release of toxic substances. The Ontario government is developing a strategy to further reduce toxic substances in air, land, water and consumer products. Monitoring informs the development of such strategies and measures their effectiveness by tracking levels of toxic substances in the environment. Sport fish and sediment monitoring as described in this report are particularly effective in tracking trends in toxic substances.

Climate change models predict a range of impacts on Ontario's water resources including lower water levels, warmer water, more extreme weather events, more droughts, flooding and erosion. Monitoring results clearly indicate that a warming climate is already affecting Ontario's water resources. For example, the types of algae in northern Ontario lakes are changing in response to warmer air temperature and longer ice-free seasons. Monitoring climate change impacts informs the development of adaptation strategies to protect water resources in the face of future changes in climate.

3.0 Phosphorus Management

What is phosphorus?

Phosphorus is an essential nutrient for plant and animal growth. In lakes and streams, phosphorus stimulates the growth of aquatic plants and algae, which provide food for aquatic animals. Scientists often refer to phosphorus as the *limiting nutrient* in water bodies because the availability of phosphorus controls the amount of plant and algae growth that can occur.

Phosphorus exists in different forms in water. It can be dissolved, bound to particles of soil and other materials, or contained within living or decaying plants. Dissolved phosphorus is most readily used by plants and algae, and is typically found in low concentrations in unpolluted water bodies. *Total Phosphorus* is a measure of all of the phosphorus in a water sample. The ministry has interim Provincial Water Quality Objectives for total phosphorus of 20 µg/L (micrograms per litre, or parts per billion) in lakes and 30 µg/L in rivers and streams to prevent the excessive growth of aquatic plants. Phosphorus is not toxic to humans and animals unless it is present at very high levels.

Where does phosphorus come from?

Phosphorus enters water as a result of both natural processes and human activities. Phosphorus is found in rocks, soil and plant material. Natural processes such as the weathering of rocks, erosion of soils and the decomposition of plants release phosphorus into water. Human activities, such as the application of fertilizers, add phosphorus to the land, which can be carried into rivers and lakes with runoff from melting snow and rain storms. The discharge of treated waste water from sewage treatment plants and industries contributes additional phosphorus.

In the past, consumer products such as laundry detergents were a major source of phosphorus in water bodies. Government regulations now control the amount of phosphates in laundry detergents. The ministry

Scientists often refer to phosphorus as the *limiting nutrient* in water bodies because the availability of phosphorus controls the amount of plant growth that can occur.

A ministry scientist identifies the species of algae in a lake water sample.

If excessive inputs of phosphorus continue over time, the natural processes operating in a water body can be disrupted and habitat can be impaired.

has taken action to reduce phosphorus inputs to water from other major sources such as sewage treatment plants and industries. The Ontario government is phasing in requirements for agricultural operations to prepare nutrient management plans to ensure the appropriate application of fertilizer and storage of nutrients on farm properties.

Why is too much phosphorus a problem?

Inputs of phosphorus to a water body can stimulate the growth of aquatic plants and algae, which provides more food for fish and other aquatic animals. Initially, enhanced plant and algae growth can lead to an increase in animal populations. However, if excessive inputs of phosphorus continue over time, the natural processes operating in a water body can be disrupted and habitat can be impaired. The excessive loading of nutrients, primarily phosphorus, to a water body from human activities is called *nutrient enrichment* or *eutrophication*. This can threaten aquatic habitat, spoil the natural beauty of lakes and streams, and cause taste and odour problems in surface and drinking water.

Excessive plant and algae growth in a water body can cause large fluctuations in dissolved oxygen concentrations. Oxygen is produced by plants and algae during the day as a product of photosynthesis. At night, however, oxygen concentrations are reduced as plants breathe. Changes in dissolved oxygen concentrations can harm aquatic habitats and increase stress on aquatic animals. Excessive plant and algae growth also results in large amounts of organic material settling to the bottom of a water body. The decomposition of the material depletes oxygen in the water, which can stress or kill fish and other animals. Some species, such as trout, need consistently high levels of oxygen to survive and reproduce (see the story on Lake Simcoe in section 3.2). As oxygen is used up, more phosphorus can be released from the bottom sediments, which can make the problem worse by stimulating even more plant growth.

Algae in Ontario's lakes and streams

There are several thousand different types of algae living in Ontario's lakes and streams. They come in many forms (single cells, colonies and filaments) and sizes. Algae take nutrients like phosphorus and nitrogen from the water and convert them into organic matter, which provides a source of food for animals like plankton and fish.

Algae require sunlight and nutrients (especially phosphorus and nitrogen) to grow. High concentrations of phosphorus can stimulate the excessive growth of algae resulting in a "bloom". Algal blooms can colour a water body green, brown or yellow, reduce the clarity of water and make the water taste and smell unpleasant. Certain species of algae can produce toxins, which can harm animals and humans. Algae can also form mats on the surface or clumps on the bottom, which can foul beaches (see the story on shoreline fouling in the Great Lakes in Section 3.3).

3.1 Phosphorus Monitoring Results

Great Lakes

The ministry has several programs to monitor changes in the water quality of the Great Lakes (see Appendix A for more information on monitoring programs). In 1976, the Great Lakes Water Intake Monitoring Program began collecting weekly samples of raw (untreated) water year-round from the intakes of 17 municipal water treatment plants that draw water from Lake Superior, Lake Huron, Lake Erie or Lake Ontario, from Great Lake connecting channels, or from the St. Lawrence River. The samples are analyzed for a range of variables (including phosphorus), and the amounts and types of algae are counted. The monitoring results have been used to assess changes in the nutrient status of the Great Lakes over more than three decades. This program was originally implemented to track

Samples are **analyzed** for a range of variables (including phosphorus), and the **amounts and types of algae** are counted.

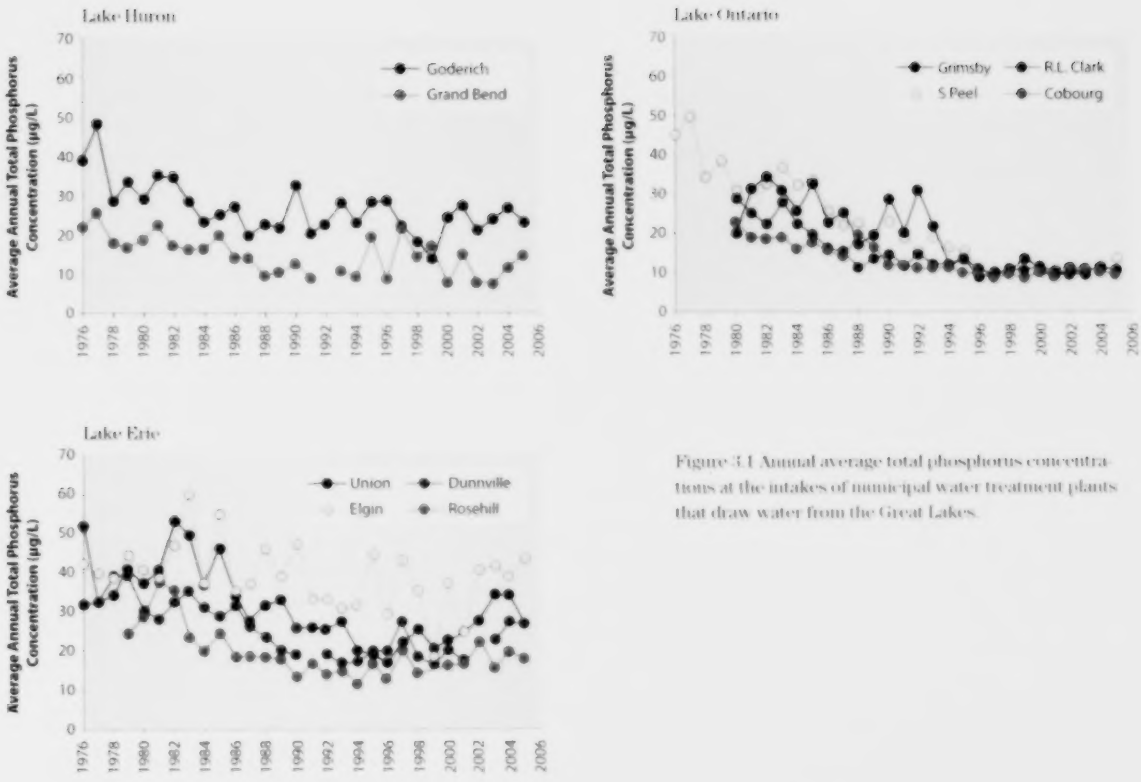


Figure 3.1 Annual average total phosphorus concentrations at the intakes of municipal water treatment plants that draw water from the Great Lakes.

the effects of nutrient reduction programs initiated under the 1972 US and Canada Great Lakes Water Quality Agreement. However, these monitoring data have proven to be useful in identifying the impacts of more recent changes in the Great Lakes ecosystem, such as the invasion of the lakes by the non-native zebra and quagga mussels, and the impacts of climate change.

There have been significant decreases in the annual average total phosphorus concentrations recorded at all of the intakes on Lake Ontario and Lake Huron, and at three of the intakes on Lake Erie (Figure 3.1). Most decreases occurred in the 1980s, following implementation of phosphorus reduction strategies. Annual average concentrations have remained relatively stable at most of the intakes since the mid-1990s.

Inland lakes

Phosphorus concentrations in many inland lakes throughout Ontario have decreased since long-term monitoring programs began in the 1970s. This is especially true for lakes with watersheds that include urban centres. Reductions in the use of phosphates in laundry detergents, improved sewage treatment and the implementation of agricultural best management practices contributed

to this decline. The Kawartha Lakes, for example, have much lower concentrations of total phosphorus now than they had 35 years ago.

The implementation of best management practices, however, is not the only reason for phosphorus reductions. There is evidence that phosphorus concentrations have decreased in lakes on the Canadian Shield that have little or no human activity in their watersheds. These cottage-country lakes have forested watersheds on thin soils over bedrock. The whole-lake, ice-free, mean total phosphorus record from Plastic Lake near Dorset, Ontario demonstrates this trend (Figure 3.2). The Dorset lakes have been studied intensively. They receive nearly all of their phosphorus inputs from forested watersheds and wetlands, from the atmosphere, and from the septic systems on shoreline properties. In the case of Plastic Lake, there are no cottages in the watershed and so there are no inputs from septic systems. Therefore, the declines in phosphorus in the lake are not related to a reduction in phosphates from laundry detergents. Although the causes for these declines are still being investigated, both acid deposition and climate change may be contributing. More frequent drought may decrease the export of nutrients to the lakes. Also, decades of acid deposition may have changed the soil chemistry, resulting in decreased export of nutrients from the watersheds. There is evidence that loss of total phosphorus (oligotrophication) is a regional phenomenon impacting lakes in many areas of Ontario. Most Lake Partner Program lakes have shown either no change or a decrease in total phosphorus concentrations since 2002, when precise analysis began. A summary of phosphorus monitoring results from the Lake Partner Program is shown in Figure 3.3.

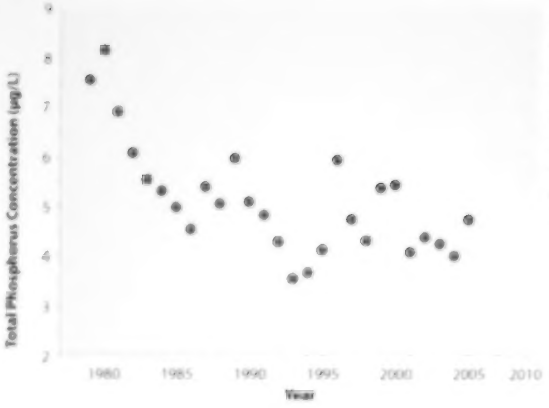


Figure 3.2 Phosphorus concentrations for Plastic Lake. Plotted values indicate annual mean phosphorus concentrations in samples collected during ice-free seasons.

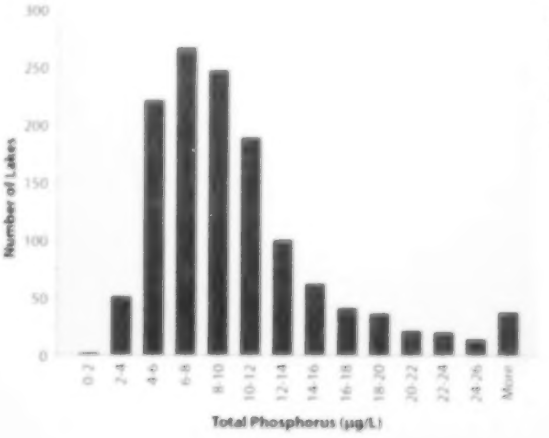


Figure 3.3 Distribution of phosphorus concentrations in 1,311 lakes monitored by the Lake Partner Program (2002-2007).

Rivers and streams

The ministry has been monitoring water quality in rivers and streams across Ontario for over 40 years as part of the Provincial (Stream) Water Quality Monitoring Network. Samples are collected monthly and analyzed in the ministry's laboratory

for a range of water quality parameters, including phosphorus. Recent results for selected watersheds (Figures 3.4 and 3.5) show that the lowest phosphorus concentrations are found in rivers and streams in central and northern Ontario where human population density is low and land cover is mostly natural. The highest concentrations of phosphorus are found in rivers and streams in southern Ontario, where the soils are relatively rich and the land has been developed for a variety of agricultural and urban uses.

Phosphorus concentrations in many rivers and streams in Ontario have declined. The general trend for rivers and streams (Figure 3.6) is consistent with the trend in the Great Lakes. Concentrations of phosphorus in rivers and streams declined significantly in the 1980s with the implementation of phosphorus reduction strategies. The reduction of phosphates in laundry detergents and improvements in the levels of treatment at most sewage treatment plants in Ontario played a significant role. However, as Figures 3.5 and 3.6 illustrate, many Ontario rivers and streams continue to exceed the interim Provincial Water Quality Objective of 30 µg/L (micrograms per litre, or parts per billion) of phosphorus. Further vigilance is needed to control human sources of phosphorus in these watersheds.

Figure 3.4 Water quality is monitored in over 100 rivers and streams across Ontario as part of the Provincial (Stream) Water Quality Monitoring Network. The 30 watersheds on the map represent a range in land use activities and geology, and illustrate the range of phosphorus levels across Ontario.

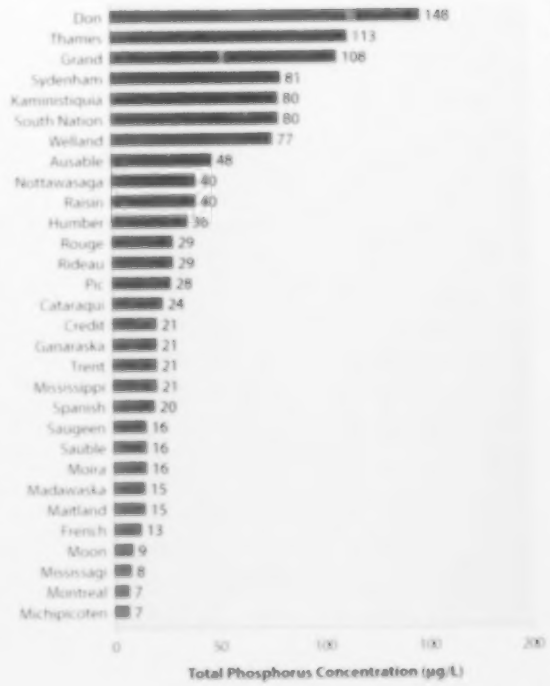


Figure 3.5 Total phosphorus concentration in 30 Ontario rivers. The median concentration is shown based on five years (2001–2005) of sampling results for each river.

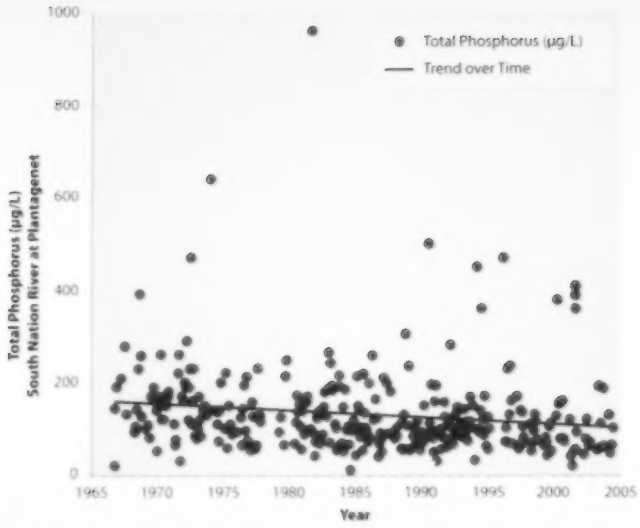


Figure 3.6 Phosphorus concentrations in the South Nation River, eastern Ontario.

3.2 Lake Simcoe Strategy

Lake Simcoe: A valuable natural resource

Lake Simcoe is a large lake less than an hour's drive from half the population of Ontario. Its watershed drains a land area of 2,840 km², from the Oak Ridges Moraine in the south to Lake Couchiching in the north, from the headwaters of the Caledon Hills in the southwest to the Kawartha Lakes in the northeast (Figure 3.7). The lake is a source of drinking water for six lakeshore communities and the watershed is home to almost 350,000 residents.

Lake Simcoe is a valuable natural and recreational resource, and has long been known for its excellent fishery. Overall the lake generates more than $200 million annually for the local economy through recreational activities.

Key Facts

Lake Simcoe, the largest inland lake in southern Ontario, is a valuable natural resource known for its excellent fishery.

Phosphorus inputs from urban and rural sources have lowered oxygen levels at the bottom of the lake. This has a significant impact on fish in the lake.

Governments and other stakeholders have been working together for the last 20 years to reduce phosphorus inputs to the lake.

Monitoring results show that phosphorus inputs to the lake from tributaries have decreased significantly and that oxygen levels at the bottom of the lake have increased; however, phosphorus inputs need to be reduced further as part of a broad strategy to restore and protect the lake.

A Lake Under Stress

Water quality problems in Lake Simcoe resulted from changing land

Figure 3.7 Lake Simcoe and its watershed

use and population growth in the watershed, and through the invasion of the lake by numerous exotic (non-native) species including zebra mussels. Water quality problems have caused reproductive problems for cold water fish like lake trout, lake whitefish and lake herring. Plants and algae also grow excessively along the shoreline. The amount of phosphorus entering the lake was three times higher during the 1980s than it was before the land changed from forested to mostly agricultural and urban. This led to substantial reductions in the amount of dissolved oxygen in the lake's deep water zones. Phosphorus enters Lake Simcoe from sources throughout the watershed, including agricultural runoff, urban storm water runoff, sewage effluent, and through atmospheric deposition to the lake's surface.

Protecting Lake Simcoe

A multi-agency partnership, the Lake Simcoe Environmental Management Strategy (LSEMS) was formed in 1980 to improve the water quality of Lake Simcoe (www.lsems.info/). The partnership grew and included the Lake Simcoe Region Conservation Authority, all levels of government, First Nations, and the watershed community.

Efforts have been made to reduce the total phosphorus input to the lake to below a target of 75 tonnes per year, so that dissolved oxygen levels of more than 5 mg/L are maintained in the deep waters of the lake at the end of the summer. Phosphorus discharges from sewage treatment plants were reduced and water quality improvement projects have reduced the amount of phosphorus delivered to the lake in urban and agricultural runoff and from septic tanks. An Assimilative Capacity Study (www.lsrca.on.ca/ACS/) was completed on Lake Simcoe in 2006. The study examined the relationship between changing land uses in the watershed and phosphorus loads to the lake. It also assessed the

impact that forecasted urban growth will have on the quality and quantity of water entering the lake.

The *Lake Simcoe Protection Act* became law on December 10, 2008. The new legislation enshrines watershed protection in law and requires the province to develop and implement a plan to protect and restore the lake's watershed and reduce the amount of phosphorus entering the lake to no more than 44 tonnes per year. For more information on Ontario's strategy to protect Lake Simcoe please go to (www.ene.gov.on.ca/en/water/lakesimcoe/index.php).

Monitoring progress in restoring the lake

The ministry started monitoring Lake Simcoe in the 1970s in partnership with the Lake Simcoe Region Conservation Authority. Each year, from spring through fall, eight stations are sampled on the open lake and three are sampled in the mouth of the Holland River. Samples are analyzed for water quality variables including nutrients (nitrogen and phosphorus), dissolved ions (e.g., chloride), dissolved organic carbon, metals and pH. Water clarity, temperature, and dissolved oxygen are measured, and samples are collected for phytoplankton and zooplankton analysis. Water samples from three municipal water treatment plants on the lake are collected weekly, all year round, for water chemistry and phytoplankton analysis.

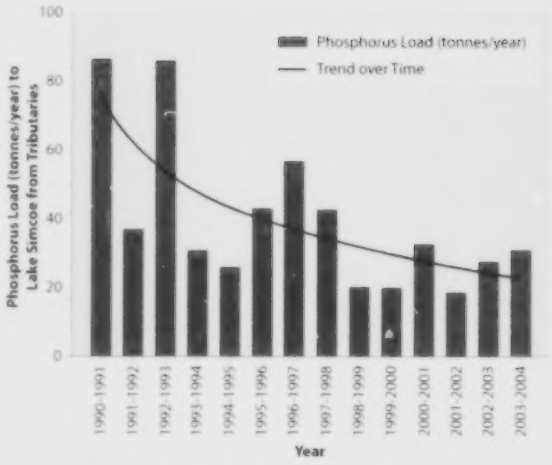


Figure 3.8 Phosphorus loads from tributaries to Lake Simcoe have decreased significantly since the early and mid-1990s.

The monitoring program for Lake Simcoe also measures nitrogen, phosphorus and chloride levels in the major rivers flowing into the lake. Wet (rain and snow) and dry (dust) deposition samples are collected to calculate atmospheric deposition rates.

The ministry works with the Lake Simcoe Region Conservation Authority, and uses additional flow and weather data from Environment Canada, to estimate the total load of phosphorus delivered to the lake each year from all sources.

Improvements in Lake Simcoe water quality

Phosphorus loads from tributary streams draining primarily agricultural and urban areas have decreased significantly since the 1990s (Figure 3.8). The total phosphorus concentration measured in Lake Simcoe in the spring has also decreased sig-

Lake Simcoe

nificantly since 1980 (Figure 3.9). Levels of dissolved oxygen in the deep waters of the lake at the end of the summer have increased, and are above 5 mg/L (Figure 3.10). These levels still remain well below 7 mg/L, the concentration considered protective of lake trout. Studies by the Ministry of Natural Resources have found that natural reproduction of lake trout and lake whitefish remains low; their populations are maintained through stocking. Excessive growth of rooted aquatic plants and attached algae remain a problem along shoreline areas of the lake. Efforts are continuing to reduce phosphorus loading to Lake Simcoe, with the added pressure of urban growth in the watershed.

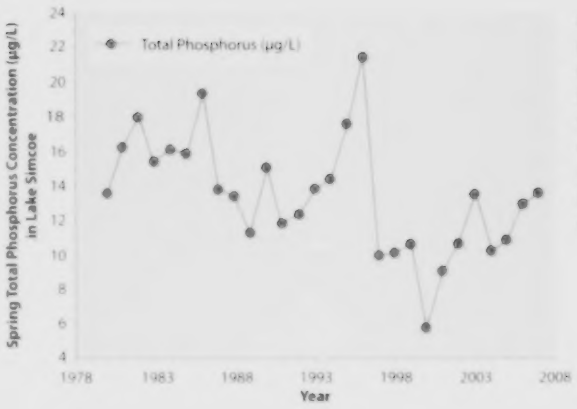


Figure 3.9 The total phosphorus concentration measured in Lake Simcoe in the spring has decreased significantly from 1980 to 2007 (whole lake volume-weighted concentration).

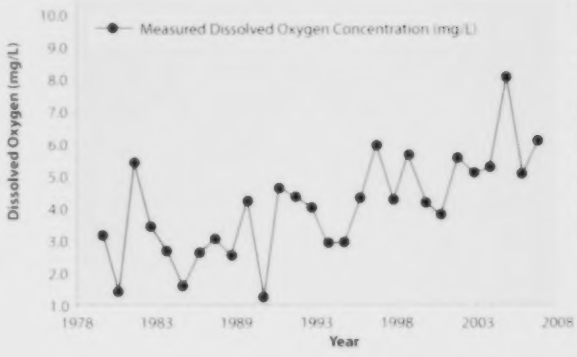


Figure 3.10 Levels of dissolved oxygen in the deep waters of Lake Simcoe in late summer have increased (minimum volume-weighted 18m to bottom concentrations from 15 June to 15 September).

Lake Simcoe

3.3 Great Lakes Shoreline Fouling

What is *Cladophora*?

Cladophora is a type of green algae that occurs naturally in the Great Lakes. It grows in branched filaments that attach to hard objects on the lake bottom, including rocks, mussel shells and breakwalls. In areas with a rich supply of phosphorus and adequate light reaching the lake bottom, *Cladophora* can completely cover the bottom in the shallow portions of the lake creating an ugly "lawn" of algae, which can be more than 10 cm thick. In early to mid summer, *Cladophora* detaches from the lake bottom and washes up on the shore. This is called *shoreline fouling*. In some areas, large quantities of rotting and foul-smelling algae pile up on the shoreline, reducing the aesthetic and recreational potential of the lakeshore. Other types of algae can also cause shoreline fouling; however, *Cladophora* accounts for most of the incidents within the Great Lakes, except in Lake Huron.

The resurgence of *Cladophora* in the Great Lakes

Cladophora fouls shoreline over a wide area in eastern Lake Erie, diverse areas in Lake Ontario, and patches around Lake Huron. From the late 1950s to the early 1980s, the overabundance of *Cladophora* and shoreline fouling was linked to elevated levels of phosphorus in the lakes, or in the case of Lake Huron, localized sources. Successful efforts to reduce phosphorus inputs to the Great Lakes over the last 30 years appeared to be having the desired effect, with little complaint of *Cladophora*-related problems from the mid-1980s to the mid-1990s. However, *Cladophora*-related complaints are now increasing. The reasons for the increase in the severity of shoreline fouling by algae are the subject

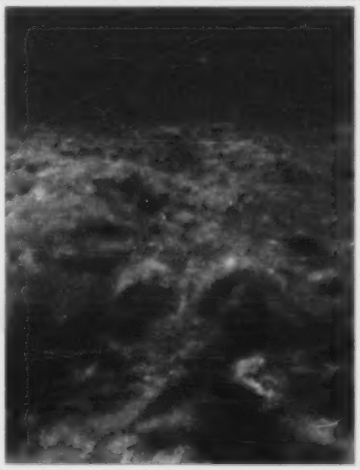
Key Facts

Areas of shoreline in the Great Lakes are being fouled with *Cladophora*, a type of green algae that normally flourishes where phosphorus is abundant.

Successful efforts to reduce phosphorus loads to the Great Lakes beginning in the 1970s alleviated the *Cladophora* problem in the 1980s; however, *Cladophora* problems have returned.

The ministry is using innovative approaches to monitor water quality conditions along the shoreline of the Great Lakes.

Zebra mussels could be contributing to the recent resurgence in *Cladophora* by creating favourable conditions for *Cladophora* growth.



Lawns of *Cladophora* growing on the lakebed of Lake Ontario in 2003.

Masses of *Cladophora* on the shoreline of Lake Ontario in 2007.

of ongoing research. The connection between high phosphorus levels and excessive growths of *Cladophora* would suggest that increased phosphorus inputs to the Great Lakes may be responsible. However, there is little evidence of recent increases in lake-wide phosphorus levels in the Great Lakes (see Section 3.1). Another possibility is that phosphorus levels are increasing locally along some areas of shoreline, and contributing to the enhanced growth of algae. The invasive zebra mussels and the closely related quagga mussels (hereafter collectively referred to as zebra mussels) could also be a factor.

The Great Lakes Guardian, a ministry Great Lakes survey vessel

How do zebra mussels enhance *Cladophora* growth?

Sunlight must reach the bottom of a lake for *Cladophora* to grow. There are beds of zebra mussels on the lake bottom in many areas of Great Lakes shoreline. Zebra mussels feed by filtering plankton and other particles from the water. The filtering action of mussels can thus clarify the water, resulting in more light penetration, which allows plants like *Cladophora* to grow at greater depths in a lake. There is evidence that *Cladophora* is covering a greater area of the lake bottom since the colonization of the Great Lakes by zebra mussels.

Zebra mussels might also be enhancing *Cladophora* growth by changing the way phosphorus is cycled (moved around) in lakes. The *nearshore shunt* hypothesis explains this. Phosphorus is attached to soil and other particles that are delivered to the shore of a lake by rivers and streams. Instead of moving offshore into the deeper part of the lake, the particles are filtered out of the water by zebra mussels in the *nearshore* (shallow areas near the shoreline) where the phosphorus builds up in the bodies of mussels and sediment. Plankton also contains phosphorus, which is filtered from the water. Excretion by zebra mussels and release from the sediment provides more phosphorus for growing *Cladophora* in the shallow areas of the lake, where the sunlight penetrates to the bottom. Phosphorus is retained in the nearshore instead of moving offshore. This has implications for managing nutrient levels in the Great Lakes, since phosphorus levels offshore may decline at a greater rate than predicted by the loading of nutrients to the lake.

The challenge is to assess the relative contribution of zebra mussels to the success of *Cladophora* compared to the role of nutrient inputs from the lands adjoining the nearshore. Background levels of phosphorus in the lake basin, the degree of local nutrient enrichment, and the extent to which zebra mussels occur in an area may also play a role.

High-tech water quality sensors are tracked along selected sections of Great Lakes shoreline.

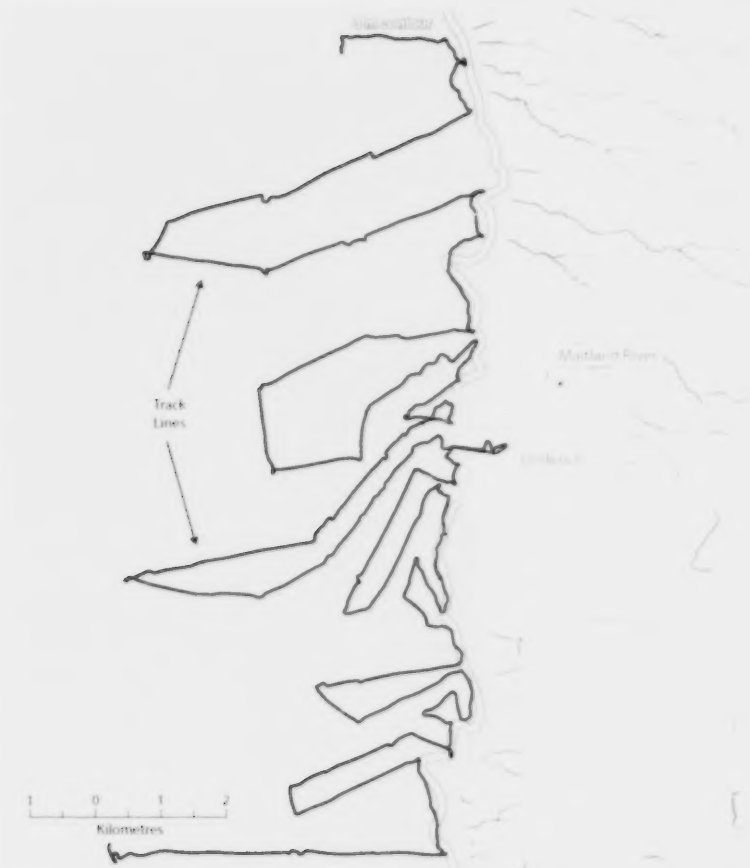


Figure 11 Water quality sensors linked to the vessel (navigation) system collect data as the vessel navigates a predetermined survey route (black line). A survey track completed in May 2001 over an area shoreline near Goderich, at the mouth of the Maitland River on Lake Huron, illustrates the scale of data collection.

Monitoring water quality in the nearshore: A challenge

Monitoring water quality along the shoreline of the Great Lakes is a formidable challenge because conditions vary greatly. Every area of shoreline has its own unique set of tributaries, from small creeks to large rivers, which affect water quality conditions over some portion of the shoreline. In developed areas there may be unique sources of land runoff or discharge to the lake. The shoreline of the Great Lakes is also subjected to strong wind-driven mixing or stirring of the water. Water discharged to the shoreline by tributaries and other sources is moved in ever-changing directions by winds and lake currents.

The ministry has developed innovative approaches to monitoring water quality in the nearshore of the Great Lakes. These approaches are helping us to understand how water quality changes in the nearshore over time and how it compares from one place to another. We are also beginning to understand the influence of phosphorus inputs from watersheds. In one approach, a ship tracks high-tech water quality sensors along the

shoreline. The ship follows a predefined survey route (Figure 3.11) and water quality measurements are logged onto computers. The resulting data set is used to map water quality conditions along selected sections of shoreline (Figure 3.12).

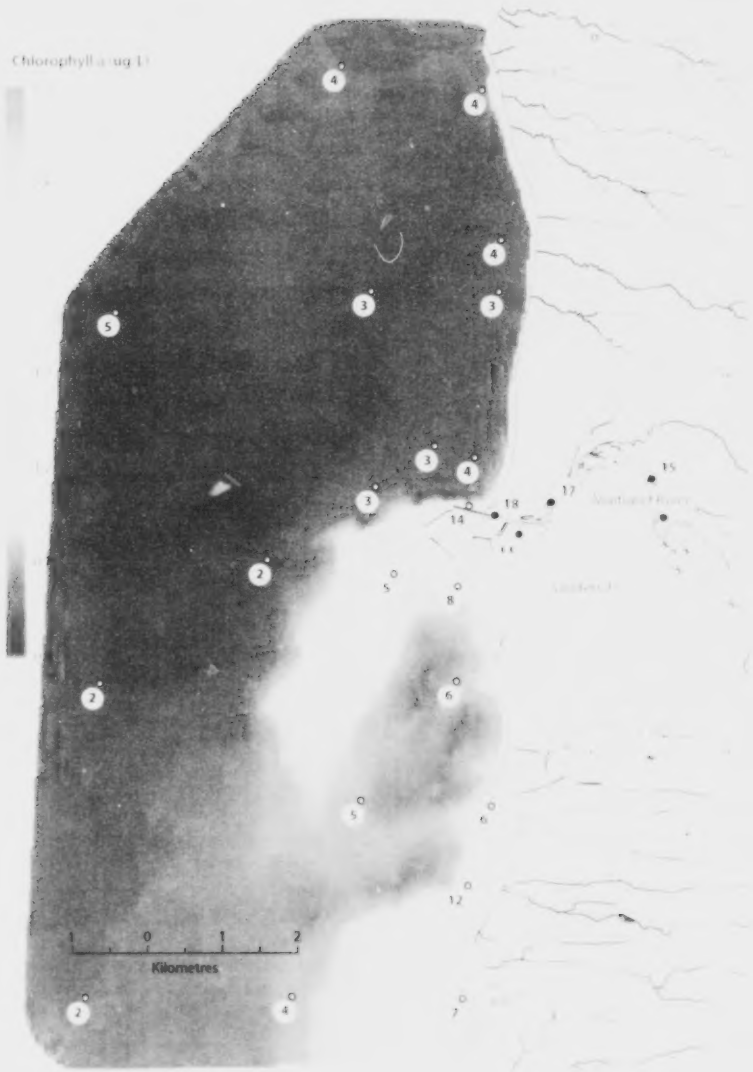
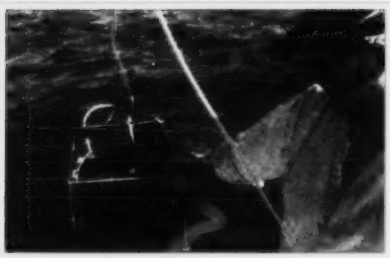
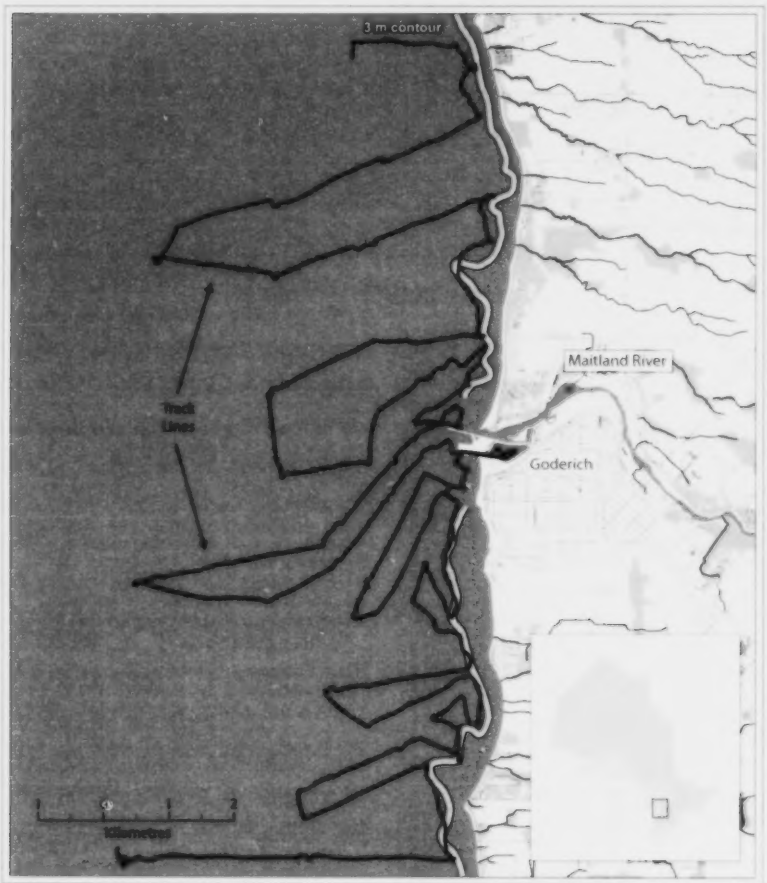


Figure 3.12 A survey in May 2001 over an area of shoreline at the mouth of the Maitland River on Lake Huron shows diverse conditions. The coloured ring indicates levels of chlorophyll a (an indicator of phytoplankton) and the numbers indicate concentrations of total phosphorus. The influence of the discharge from the Maitland River to the south of the river mouth and the contrast in levels of chlorophyll a and total phosphorus among the shoreline north and south of the Maitland River and between nearshore and offshore areas are evident.



High-tech water quality sensors are tracked along selected sections of Great Lakes shoreline.



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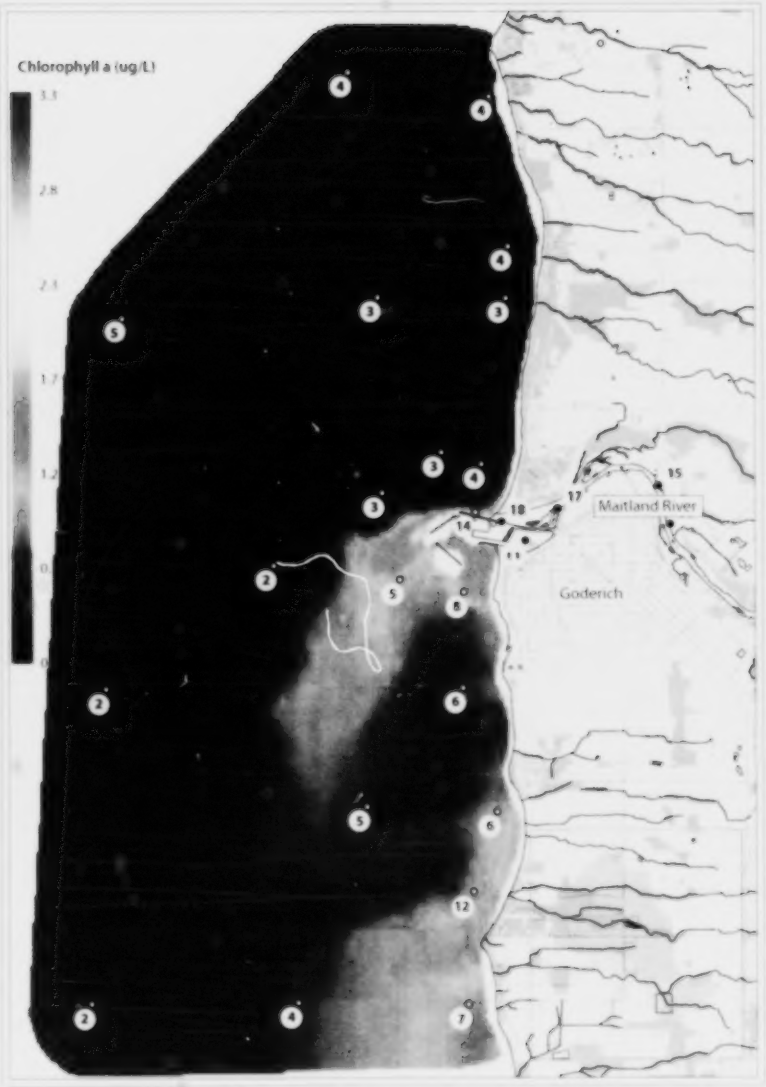

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Monitoring nutrient levels along areas of shoreline provides information needed to examine the potential of the lake basin and land-based nutrient inputs to promote *Cladophora* growth. It is difficult to determine the degree to which zebra mussel-related effects contribute to the excessive growth of *Cladophora* since both zebra mussels and lawns of *Cladophora* are widely distributed within a lake basin (see Figure 3.13).

Figure 3.13 Beds of *Cladophora* cover areas of the shallow lakebed in eastern Lake Erie. Monitoring indicates that the occurrence of *Cladophora* beds is widespread over areas of bedrock. Thickness (cm) of lawns of *Cladophora* over the lakebed in eastern Lake Erie during July surveys in 1995, 1998 and 2001 are shown. Measurements were made at depths of 0.5 to 1.5 m. *Cladophora* requires hard or physically stable soil or rock to attach to, because of the strong waves in the nearshore.

4.0 Acid Rain

Governments and industry in Ontario have worked together to reduce emissions of air pollutants that cause acid deposition or acid rain. Long-term water quality monitoring by the ministry and its partners shows that many Ontario lakes have responded positively to reductions in emissions. The greatest improvements in Ontario have occurred in the Sudbury region, where emissions of acid-causing pollutants have declined by 90% in the last 40 years (see the story on Sudbury in Section 4.1). However, monitoring also shows that many Ontario lakes are still affected by acid deposition and are in the process of recovery.

What is acid rain?

Acid rain is rain that has become more acidic than normal by mixing with pollutants in the atmosphere. The term is often used to describe the various acidic substances (wet and dry) that are deposited from the atmosphere. A more precise term is *acid deposition*, which includes wet deposition (rain, snow and fog) and dry deposition (dust particles and gases).

Two air pollutants are primarily responsible for acid deposition – sulphur dioxide and nitrogen oxides. These gases react with water and bond to other substances (e.g., dust particles) in the atmosphere to produce various acidic compounds (e.g., sulphuric and nitric acids). In Ontario, sulphur dioxide is produced primarily from the burning of coal to produce electricity and the smelting of sulphur-containing ores. Nitrogen oxides are produced during the combustion of fossil fuels. Air pollutants can travel hundreds of kilometres in the atmosphere. Ontario is exposed to its own acid emissions, and to the long-range atmospheric transport of pollutants from other provinces and the northeastern United States.

How does acid deposition affect aquatic environments?

Acid deposition increases the acidity (lowers the pH) of a water body. This can result in dramatic changes to the types of plants and animals that live there because many of them cannot reproduce or survive in an acidified environment. The number of different kinds of plankton and fish decreases as water bodies become more acidic. Some lakes become too acidic to support fish at all.

Did you know?

Normal rainwater is usually slightly acidic. Acid rain is substantially more acidic. Acidity is measured on the pH scale where a pH of 7 is neutral. Acidity increases tenfold with a decrease in pH of 1. Normal rainwater has a pH of approximately 5.6 whereas the average pH of rain in Ontario is 4.2 to 4.5 – that is 10 times more acidic than normal rainwater.

Acid deposition also has other effects on water quality. As acid precipitation moves through the watershed, aluminum and other metals contained in the soil are released into streams and lakes. Elevated concentrations of metals can have toxic effects on aquatic species. Years of acid deposition can also deplete acid-neutralizing chemicals (e.g. calcium) present in soils, thus making the watershed more susceptible to further acidification. Because sulphur is stored in wetlands and lake-shoreline sediments, waterbody recovery following reduced acid deposition can be delayed because of periodic releases of sulphur from sediment, as commonly happen

following periods of drought (see Chapter 6: Climate Change). Studies also suggest that the concentration of dissolved organic carbon (DOC) is reduced in acidified lakes, which results in clearer water. This could make aquatic species more susceptible to ultraviolet-B (UV-B) radiation. Research in this area is continuing.

Which areas are most affected by acid deposition?

Some areas, like southern and central Ontario, receive higher amounts of acid deposition because of their proximity to acid-causing emissions and the prevailing wind patterns. However, the bedrock of most of southern Ontario is limestone. Limestone contains calcium that dissolves in water, increasing the hardness of the water in streams and lakes. Hard water has the capacity to neutralize acid deposition, the same way an antacid tablet neutralizes stomach acid. On the other hand, some areas that experience less acid deposition have reduced capacity to neutralize acid deposition because of their thin soils and granite bedrock. The bedrock of central and northern Ontario is mostly granite (Canadian Shield) including the Muskoka, Haliburton, Parry Sound, Nipissing and Sudbury regions. Streams and lakes in areas of granite bedrock have soft water with very little acid neutralizing capability. These soft-water ecosystems are most susceptible to damage from acid deposition.

Are we making progress?

Efforts to control emissions of air pollutants that cause acid deposition have been underway since the 1970s.

Long-term monitoring studies in the Dorset (central) region of Ontario have shown that lakes and streams are recovering from acid rain. This is primarily because there have been large decreases in SO_2 (sulphur dioxide) emissions in eastern North America, which have led to decreases in the deposition of atmospheric sulphur. About 75% of lakes in the region are now receiving acid inputs that are low enough to allow them to recover. Acidity is no longer rising, and pH and alkalinity have risen in the Dorset region lakes. There has been biological recovery of animal communities in some streams and lakes, although research has shown that the biological recovery of stressed systems is not guaranteed.

Despite these encouraging signs, uncertainty remains with respect to acid rain. Declines in lake sulphate are not as great as would be expected, considering the large decreases in atmospheric deposition. There are two explanations. First, the current acid deposition rates may still exceed the acid-neutralizing capacity of many watersheds. In some lakes, the decrease in lake sulphate has been accompanied by decreases in calcium. The calcium pools on the Precambrian Shield have been depleted, thus a source of acid-neutralizing potential has been weakened. Second, the sulphur that has previously been stored in wetlands can become mobile when exposed to the air. This happens when water levels are lowered during periods of drought. When these areas are once again flooded with water (usually in the fall) this sulphur is flushed from the wetlands to the lakes, causing re-acidification.

Since the 70's, **the Ontario government has been working cooperatively** with industries and other governments, including State governments **to reduce acid-causing emissions.**

The recent Canadian Acid Deposition Science Assessment concluded that further reductions in acid emissions are warranted, and that additional reductions would reduce the percentage of lakes (25%) that are still receiving excess acid inputs from the atmosphere.

4.1 Recovery of Lakes in the Sudbury Region

Acidification of Sudbury lakes

In Ontario, the damaging effects of acid deposition from the atmosphere were first recognized in lakes around the metal mining and smelting complexes near Sudbury. It is estimated that over 7,000 lakes in a 17,000 square kilometre zone around Sudbury were acidified by sulphur deposition associated with emissions from metal smelters (Figure 4.1). Lakes closest to Sudbury were also contaminated with metals that were abundant in the smelter emissions, especially copper and nickel. Species in these lakes that could not tolerate the higher levels of metals and acidity were reduced in number or eliminated.

Figure 4.1 The Sudbury region of Ontario. Over 7,000 lakes in a 17,000 km² zone (the shaded area) around Sudbury were acidified by sulphur deposition associated with emissions from metal smelters.

Key Facts

Studies in the 1970s found that lakes in the Sudbury region had been acidified by emissions from metal smelters.

Pollution controls implemented at the smelters in the 1970s and 1990s have reduced local acid-causing emissions by 90%. Reduced emissions have resulted in improvements in water quality in some lakes in the region; however, many lakes are still recovering.

Long-term monitoring studies in the Sudbury region are being used to understand the recovery of acidified lakes throughout the world.

Recovery of Sudbury lakes

Pollution controls implemented at the smelters have resulted in huge reductions in local sulphur emissions since the 1960s (Figure 4.2). Emissions of metal particulates have also been reduced.

Reduced smelter emissions have resulted in changes in the water quality of lakes in the Sudbury region. This includes increased pH (decreased acidity) and decreased concentrations of sulphate, base cations (calcium, magnesium) and metals (copper, nickel, aluminum). Water quality changes in Whitepine Lake, located 89 km north of Sudbury in the area impacted by sulphur deposition, are shown in Figure 4.3.

While some Sudbury area lakes have shown improvement, many lakes are still severely acidified, and recovery is continuing. The long-range atmospheric transport and deposition of sulphur provides acid inputs to many lakes. The ministry is continuing to monitor Sudbury lakes to determine the long-term chemical responses to reduced acid deposition.

Biological recovery has been observed in some lakes among various groups of organisms including fish, phytoplankton, benthic invertebrates and zooplankton (Figure 4.4). In many lakes, biological recovery is still at an early stage. Other lakes have improved to the point that successful re-introductions of sport fish have been possible.

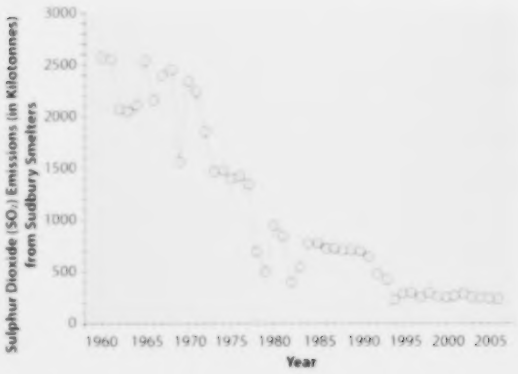


Figure 4.2 Sulphur dioxide (SO_2) emissions from Sudbury smelters have been reduced by 90% since the 1960s.

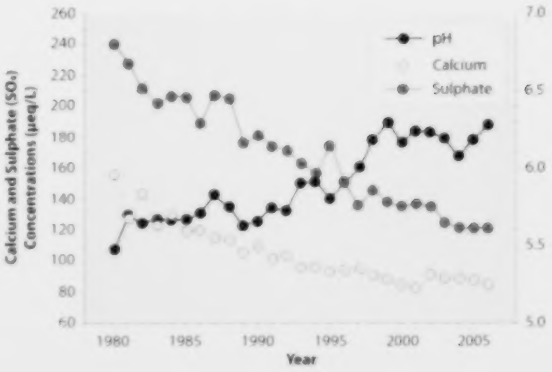


Figure 4.3 Whitepine Lake, located 89 km north of Sudbury in the area impacted by sulphur deposition, is showing signs of recovery. Concentrations of sulphate (SO_4) and base cations (calcium) are decreasing and pH is increasing.

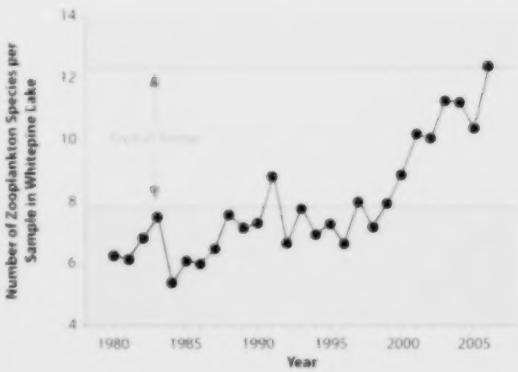


Figure 4.4 The number of species of zooplankton in Whitepine Lake is increasing as water quality in the lake improves. The dashed lines represent the typical range in number of zooplankton species in 22 non-acidic lakes located near Dorset, Ontario.

It has become clear that the chemical and biological recovery of the Sudbury lakes from acidification is closely linked to the effects of other major environmental stressors such as climate change.

Since periods of drought can lead to lake re-acidification, this can have

severe consequences for the biological recovery of lakes (see Chapter 6 Climate Change). Future studies of the recovery of acid-damaged lakes will need to be conducted in the context of multiple interacting stressors.

Studies of Sudbury lakes are giving us an understanding of chemical and biological lake recovery processes at a time when evidence of aquatic recovery from acidification is just starting to emerge from other acid-affected areas of the world. Ongoing monitoring of lakes around Sudbury has shown that efforts by industry to reduce pollution are effective, and that regulatory mechanisms to encourage and enforce these measures are justified. Studies of the recovery of Sudbury area lakes contributed substantially to the debate for the revision of the *US Clean Air Act* in 1990. The *Canada-United States Air Quality Agreement* was signed in 1991 to address issues of transboundary air pollution related to acid rain. These studies continue to have local, national and international relevance. Results from Sudbury area studies were an important part of the 2004 Canadian Acid Deposition Science Assessment Report.

Cooperative Freshwater Ecology Unit

The Cooperative Freshwater Ecology Unit (Co-op Unit) was established in 1989 at Laurentian University. The Co-op Unit was created to share resources and create effective working relationships between government, industry, and universities in order to effectively address important applied environmental science questions. It is a unique partnership between the University, the Ministry of the Environment, and the Ministry of Natural Resources. Other partners include the mining industry and Environment Canada.

The goals of the Co-op Unit are to:

- understand the functioning of industrially damaged aquatic ecosystems;
- assess and monitor the process of recovery and rehabilitation after the implementation of pollution control measures;
- develop and test assessment approaches and rehabilitation techniques;
- create research and training opportunities for undergraduate and graduate students in the field of restoration ecology; and,
- contribute to an educational and science transfer program to benefit students, government, industry, and the public.

Much of the past work of the Co-op Unit has focused on assessing the chemical and biological responses of the acidified and metal-contaminated aquatic ecosystems around Sudbury to the massive reductions in smelter emissions achieved in recent decades. Aquatic acidification and metal contamination, and recovery from these stressors continue to be an important aspect of Co-op Unit studies. But, it is now recognized that these issues, and others such as climate change and UV-B irradiance, need to be addressed in a much broader environmental and geographical context, and the long-term monitoring programs of the Co-op Unit are now evaluating multiple stressor effects in northern Ontario. The Co-op Unit has established the Northern Ontario Benthic Invertebrate Reference Condition Biomonitoring Network to assist with the assessment of the effects of various stressors, particularly metal mining discharges, in lakes and streams across northern Ontario.

5.0 Toxic Substances

The ministry routinely monitors for toxic substances by collecting and analyzing samples of water, sediment and fish tissue.

What are PBT substances?

Persistent, bioaccumulative and toxic substances (PBTs) are long-lasting chemicals that can build up in fish, wildlife, and humans to levels that can be harmful to human and ecosystem health. These substances are very stable; they do not break down easily, and they are particularly difficult and expensive to clean up once they are released to the environment. Many of these substances are human-made, and have only been in existence for a relatively short period of time. Others, such as mercury and fluoride, occur naturally in the environment. In some areas of Ontario, background concentrations of naturally occurring substances exceed water quality standards for the protection of aquatic ecosystems and human health. Fluoride in groundwater is discussed later in this chapter. A primer on toxic substances is included in Appendix B.

Where do PBT substances come from?

In the past, PBT substances were released into air and water from industries, spills and pesticide applications. In the 1970s and 1980s, government regulations banned some chemicals, limited the amounts of chemicals that could be released in industrial discharges and changed pesticide use practices. These actions dramatically reduced the amount of certain targeted PBT substances in the environment. However, new chemicals used in consumer and building products have been found in increased concentrations in the environment. For example, PBDE (polybrominated diphenyl ether) flame retardants enter the environment by leaching out of plastics, furniture, carpets, and foam products.

Some PBT substances, including mercury, polychlorinated biphenyls (PCBs), and pesticides, can be carried long distances from their sources through the air. They enter the aquatic environment through precipitation and other processes, resulting in some contamination in even the most remote lakes and streams.

How do PBT substances harm the environment?

Many PBT substances have provided society with considerable benefits. However, the same properties that made these chemicals useful have also allowed them to build up in our environment and in humans, fish and wildlife.

PBT substances can impact animal and human health, including increased risks of cancer and effects on the nervous and reproductive systems. Human exposure to PBTs is often associated with diet, particularly if large amounts of fish are consumed from contaminated areas. Humans, as well as many birds, fish, and mammals, are at the top of the food web. This results in higher exposure to PBT substances, since PBTs reach higher concentrations as they move upwards in the food web. There have been considerable efforts to remove these chemicals from use and reduce their occurrence in the environment.

How is the ministry monitoring PBT substances?

The ministry routinely monitors for PBT substances in our environment by collecting and analyzing samples of water, sediment and fish tissue from lakes and streams across Ontario. PBT substances tend to concentrate in fish tissues and in sediment.

A sediment core is collected from the bottom of a water body. Analysis of the layers of sediment in the core reveals a lot of information about the history of a water body, including long-term changes in water and sediment quality.

Sport fish from the Canadian Great Lakes and inland lakes and streams across the province are monitored for PBT substances. The information collected is published in the *Guide to Eating Ontario Sport Fish*, which gives advice on how much fish of various sizes from a particular location may be eaten safely. PBT substances are measured in sediment and young-of-the-year fish in streams, lakes and the Canadian Great Lakes at selected locations to determine if there are sources impacting sediment and water quality. Water monitoring is undertaken to:

- see how much of the PBT substances are still entering into the Canadian Great Lakes;
- monitor for pesticides in urban and agricultural areas; and,
- identify ongoing sources of PBTs, so action can be taken to reduce or eliminate these sources.

Long-term monitoring programs have provided the scientific information necessary to:

- identify ongoing or emerging problems;
- determine whether levels of PBTs in the environment exceed provincial guidelines for the protection of humans, fish and wildlife; and,
- evaluate the effectiveness of regulatory actions and remediation efforts, and develop new policies and regulations.

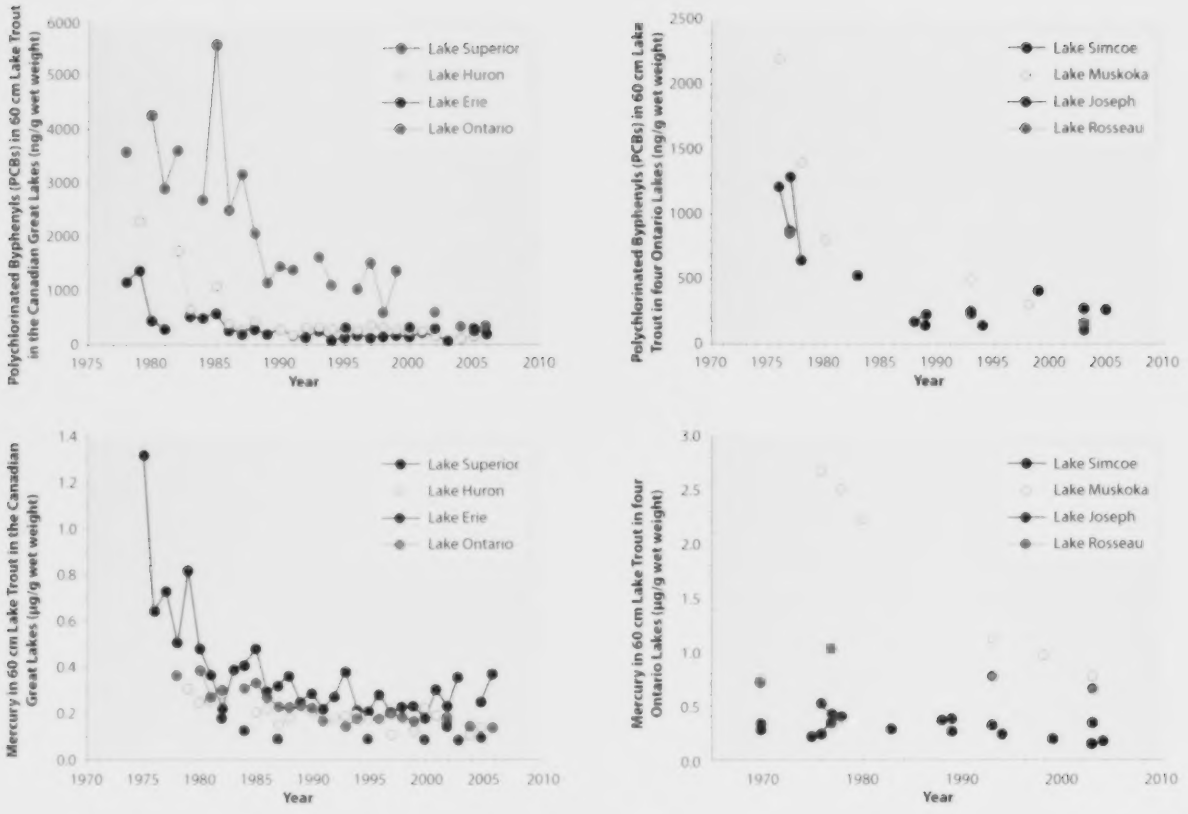


Figure 5.1 Concentrations of PCBs and mercury have decreased over time in lake trout from the Canadian Great Lakes and four Ontario inland lakes, but lower levels of contamination remain.

The ministry works closely with partner organizations to share scientific expertise and equipment, and to co-ordinate efforts in environmental monitoring. The Ontario Ministry of Natural Resources collects many of the fish that are analyzed. Contaminant monitoring in the Canadian Great Lakes is conducted in conjunction with Environment Canada, and much of the stream sampling is conducted by Conservation Authorities across the province. In areas where there are contaminated sediments or sites, the ministry works with Environment Canada and municipalities to assess the problem, guide remediation efforts and evaluate the effectiveness of these efforts.

Sediment provides a history lesson

Sediment consists of soil, plant debris and other small particles that have settled to the bottom of a water body. In streams, sediment is constantly being picked up and moved around by running water. However, in slow moving and still waters such as lakes, sediment gradually builds up on the bottom over time. Older sediment is gradually buried beneath new sediment to form layers.

Scientists insert a long, hollow tube into the sediment to collect a sample called a sediment core. The layers in the sediment core reveal the history of

a lake, including water and sediment quality, inputs of chemical contaminants, and what species were present at different times.

What is monitoring telling us about PBT substances?

PCBs, dioxins and furans are the major PBT substances of concern in the Canadian Great Lakes, while mercury concentrations are the major concern for many inland lakes.

Long-term monitoring of chemical concentrations in sport fish from Ontario has shown that levels of PBT substances, particularly PCBs and mercury, in the Canadian Great Lakes and inland lakes are generally decreasing (Figure 5.1). Large declines resulted from government action to ban and limit PBTs. However, lower levels of contamination remain due to the stable nature of these substances, their continued use in some applications and the difficulty and cost of cleaning up contaminated areas. Levels of pesticides such as DDT, toxaphene and mirex, have decreased significantly and generally are no longer of concern.

As the environment is impacted by changing land uses (e.g., urban development), invasive species and climate change, ongoing monitoring will indicate how these changes impact the degree of chemical contamination in our lakes, streams and wildlife.

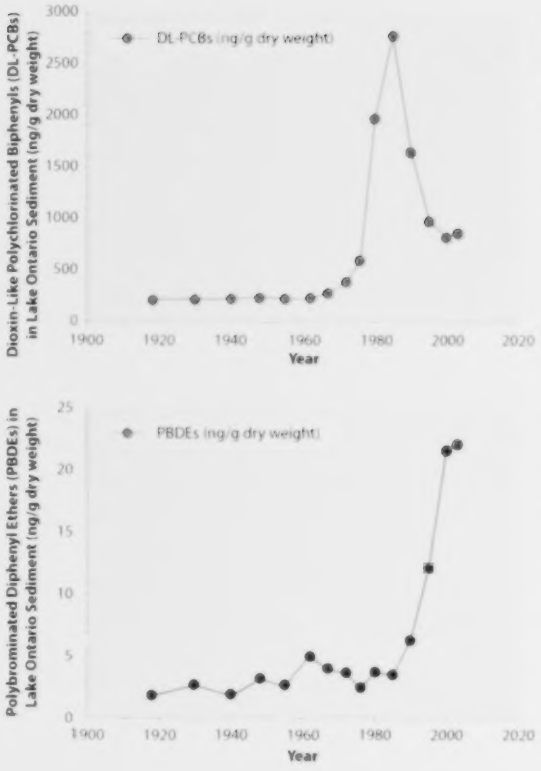


Figure 5.2

(a) Concentrations of dioxin-like PCBs in Lake Ontario sediment have declined dramatically since the 1980s when the import and manufacturing of PCBs were banned.

(b) Concentrations of PBDEs in Lake Ontario sediment have increased dramatically since the 1980s.

Monitoring for historical trends of PBT substances in sediment cores is another example of the type of information that is collected by the ministry. The ministry is working with Environment Canada to collect and analyze sediment cores from the Great Lakes to evaluate the effectiveness of programs in Ontario, Canada, and the United States in reducing inputs of PBT substances, such as PCBs. Lake Ontario, the lake furthest downstream in the Great Lakes basin, has received contaminant inputs from industry and urban areas within its own watershed and from the upstream lakes. The ministry and Environment Canada collected a core from the middle of Lake Ontario in 2004. The core was sectioned into 1 cm thick sediment slices and levels of PBT substances were measured in each slice. Each slice was also dated to provide an indication of when there were changes to inputs of PBT substances to the lake. Figure 5.2 (a) shows the trend for dioxin-like PCBs, indicating that concentrations have declined dramatically since the 1980s, after the import and manufacturing of PCBs were banned. However, low

5.1 Restoring Hamilton Harbour

levels of dioxin-like PCBs remain. As is the case in fish, concentrations in sediment have also levelled off in recent years. Figure 5.2 (b) shows an example of an increasing trend in the sediment core for the PBDE flame retardants. Use of PBDEs increased in the 1980s and 1990s, resulting in more emissions to the environment. Recent regulations in Europe, Canada and many of the U.S. states have restricted or banned the use of some PBDE mixtures. Monitoring sediment cores or archiving fish tissues and sediment samples for future analyses of chemical compounds in use today will help identify concerns and prioritize government efforts to reduce their potential impacts.

Monitoring sediment cores or archiving fish tissues and sediment samples for future analyses of chemical compounds in use today will help identify concerns and prioritize government efforts to reduce their potential impacts.

About Hamilton Harbour

Hamilton Harbour is one of the most severely polluted water bodies in Ontario. The harbour is located at the western end of Lake Ontario in a 500-square kilometre watershed. Over half a million people live in the watershed, which includes the cities of Burlington and Hamilton.

Over the last 200 years, the lands around the harbour were developed for a variety of urban, agricultural and industrial uses. The release of substances from these land uses resulted in the contamination of the harbour. The harbour was identified as an international Area of Concern, and a Remedial Action Plan was prepared in 1992 to recommend actions for cleaning up the harbour. A number of actions have been implemented, and more are planned.

What is monitoring telling us?

The ministry is monitoring Hamilton Harbour on an ongoing basis to track progress in cleaning up the harbour, and to develop strategies for the future. While the harbour is monitored for a variety of different contaminants, the high levels of PCBs in sediment in some areas of the harbour are a major concern. PCBs chemically bond to sediment particles and settle to the bottom of water bodies. PCBs contaminate the benthos (invertebrates) that live in the sediment, and the benthos are eaten by fish.

Key Facts

Hamilton Harbour, at the western end of Lake Ontario, is contaminated with many substances including PCBs.

Governments have taken actions to reduce the release of PCBs to the environment and to restore Hamilton Harbour.

Monitoring shows that levels of PCBs have decreased in fish and sediment in Hamilton Harbour.

There is a need for continued vigilance, however, as PCB levels in Hamilton Harbour are not decreasing as quickly as they did in the past and most of the fish from the harbour are still not safe to eat.

The *Guide to Eating Ontario Sport Fish* provides advice on the consumption of fish from Ontario's lakes and streams. The 2009-2010 edition advises the public that many species and sizes of sport fish from Hamilton Harbour are not safe to eat because they contain elevated levels of PCBs.

In 2003, the ministry completed a survey of the sediment in the Windermere Arm of the harbour, in collaboration with Environment Canada. This area of the harbour has the highest concentrations of PCBs

in the sediment. The survey demonstrated that PCB concentrations in deeper sediment are several times higher than concentrations in the surface sediment. These results suggest that PCB inputs to the harbour have been decreasing over time, and that the trend of decreasing PCB concentrations in fish (Figure 5.4 PCB trend in brown bullheads) is related to decreasing PCB inputs. Only the top 10 cm of sediment act as a potential contaminant source to benthic invertebrates and fish. Once buried by relatively "cleaner" sediment, the deeper more contaminated sediment is removed from the food chain so long as it is not disturbed by shipping or other activities like dredging.

This decrease shows the success of PCB management programs. However, there is still a concern, as PCB concentrations in fish are not declining as quickly as they did in the past, and concentrations in fish are still too high for safe human consumption. In spring 2007, ministry scientists initiated a comprehensive monitoring program for all of the major inputs to Hamilton Harbour – including streams, canals and waste water treatment plants. Results will be used to determine if there are ongoing local sources of PCBs that can be controlled, and to develop strategies for continuing the restoration of the harbour.

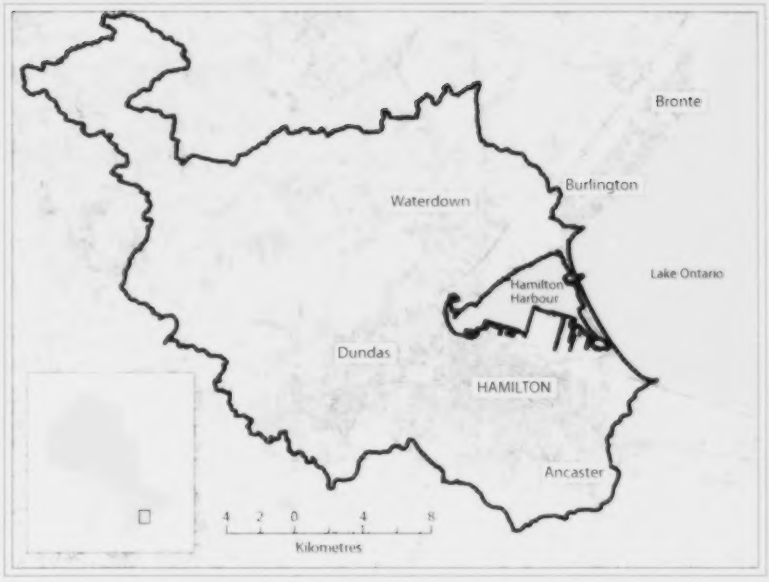


Figure 5.3 Hamilton Harbour and its watershed

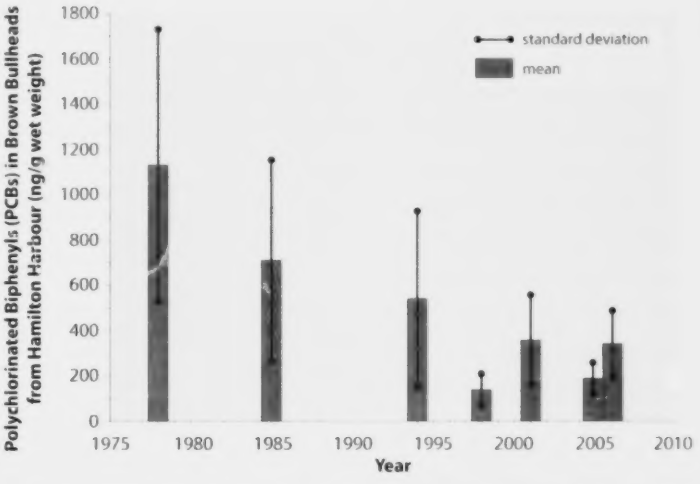
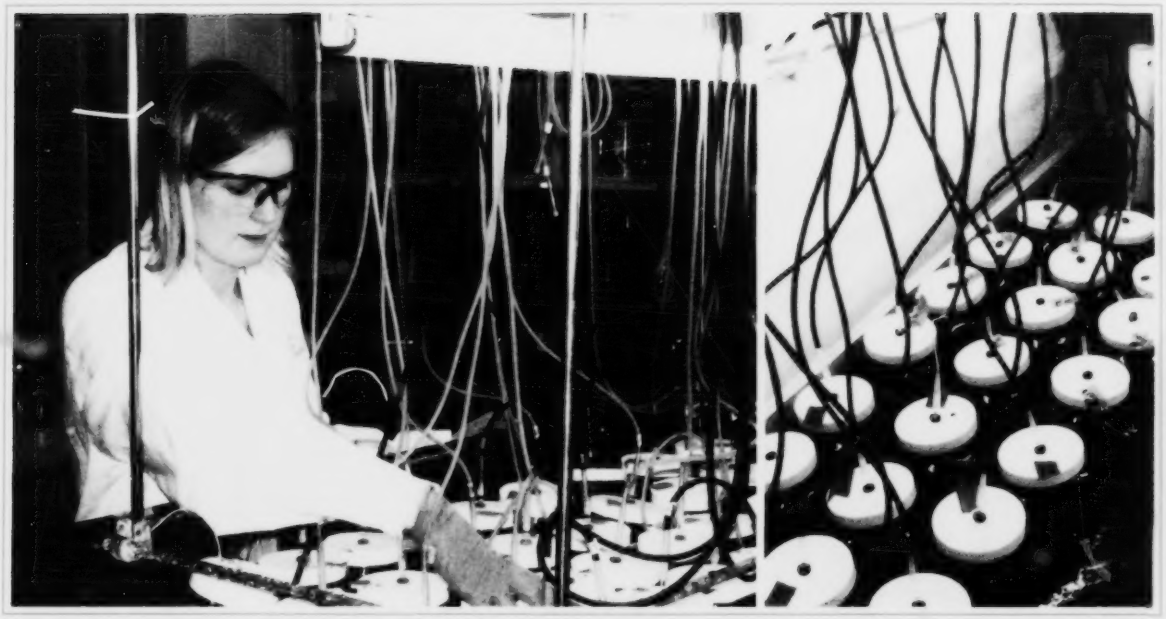


Figure 5.4 Concentrations of PCBs are decreasing in brown bullheads from Hamilton Harbour, suggesting that PCB inputs to the harbour are also decreasing over time. Brown bullheads are a species of catfish that live at the bottom of lakes and feed mostly on insects and plant material in the sediment.



Experiments are conducted in the ministry's laboratory to determine if contaminants in the sediment are being taken up by fish.

What are we learning from laboratory experiments?

To more fully understand the link between PCBs in the sediment and the animals that live in or near the sediment, sediment samples were collected from the harbour for a laboratory experiment. Laboratory fish (fathead minnows) were kept alive in a closed container with the sediment. After three weeks, the fish tissue was analyzed. The results demonstrated that the PCBs in Hamilton Harbour sediment are in a form that is easily taken up by fish, or bioavailable. The results were also useful in showing the relationship between PCB concentrations in sediment and the expected PCB concentration in fish living on the bottom of the harbour.

Clean-up of Randle Reef

In addition to elevated levels of PCBs in sediment from Windermere Arm, another sediment contamination issue in Hamilton Harbour is the elevated levels of polycyclic aromatic hydrocarbons (PAHs) in an area of the Harbour known as Randle Reef. While PCBs are a concern due to the passage of this contaminant up the food chain (bioaccumulation), the PAHs at Randle Reef are a concern due to their immediate (acute) and long-term (chronic) toxic impacts on local fish and wildlife. The contamination is the result of historical deposits of coal tar from industries that have since ceased operations. The clean-up of Randle Reef has been identified as a vital component in the restoration of the harbour. The Province of Ontario is working with federal and municipal partners to share the costs of designing and building a containment facility around the contaminated sediment to prevent toxic substances from spreading throughout the harbour.

5.2 Fluoride in Groundwater in Southwestern Ontario

Scientists from the ministry and partner organizations work cooperatively to collect groundwater samples from monitoring wells across Ontario.

Key Facts

The ministry has programs to monitor groundwater conditions across Ontario.

Fluoride is a chemical compound that occurs naturally in the environment. Fluoride is commonly found in groundwater in Ontario.

Elevated levels of fluoride have been found in the groundwater in southwestern Ontario. The levels are a product of the geological history of the region.

How do we monitor groundwater quality?

Ontario has a Provincial Groundwater Monitoring Network, which consists of over 450 monitoring wells located throughout the province. These wells provide scientific information on groundwater quality and levels. The locations of the monitoring wells were carefully selected to measure groundwater conditions in different regions of Ontario. Water samples are collected from the monitoring wells and taken to a laboratory where they are analyzed for a variety of chemicals. The information that is collected helps us understand groundwater conditions across the province. Groundwater quality is also monitored at selected municipal drinking water systems under the Ontario Drinking Water Surveillance Program, which provides information on the quality of raw (untreated) water and treated drinking water. The raw water quality data can be used to assess ambient environmental conditions, and complements the information collected by the Provincial Groundwater Monitoring Network.

How much fluoride is too much?

Fluoride in drinking water helps in the development of teeth and bone. Fluoride can be added to drinking water as part of the treatment process. Where fluoride is added, the ministry recommends that the concentration be adjusted to 0.5 to 0.8 mg/L (milligrams per litre, or parts per million), the optimum level for control of tooth decay. High concentrations of fluoride can cause dental fluorosis, which can damage the tooth-forming cells and cause increased porosity of the tooth enamel. This can lead to discolouration, pitting, chipping, fracturing, and

Samples of raw (untreated) water collected from a municipal drinking water treatment plant provide information on the water quality of surface and groundwater sources.

Groundwater quality is also monitored at selected municipal drinking water systems under the Ontario Drinking Water Surveillance Program

tooth decay. Ontario has a Drinking Water Quality Standard for fluoride (1.5 mg/L) to prevent excessive exposure. Where drinking water supplies contain naturally occurring fluoride at levels higher than 1.5 mg/L but less than 2.4 mg/L, the Ontario Ministry of Health and Long-Term Care recommends an approach through local boards of health to raise public and professional awareness to control excessive exposure to fluoride from other sources.

What does groundwater monitoring tell us about fluoride?

Monitoring results from the ministry's Provincial Groundwater Monitoring Network and Drinking Water Surveillance Program show that fluoride is commonly found in groundwater in Ontario at concentrations below the Ontario Drinking Water Quality Standard. However, 24 of the 173 monitoring wells located west of Guelph in southwestern Ontario showed levels of fluoride higher than the standard. Monitoring results from these programs are shown in Figure 5.5.

Monitoring shows that fluoride concentrations can vary considerably between wells. Many wells show concentrations lower than the Ontario Drinking Water Quality Standard, even in areas where the geology could produce water that is high in fluoride. This demonstrates the complexities of groundwater quality.

What is the ministry doing with the monitoring results?

When groundwater quality results for a substance are found to exceed an Ontario Drinking Water Quality Standard, under the Provincial Groundwater Monitoring Network, notices are immediately sent to the local health unit, Conservation Authorities, and other local officials. An assessment of the hydrology (properties of the water) and geology is conducted to look at the potential causes, and a report is produced by the Ministry of the Environment.

The reports for southwestern Ontario concluded that fluoride is naturally occurring in groundwater. As shown on the map, all of the wells with elevated fluoride levels are located

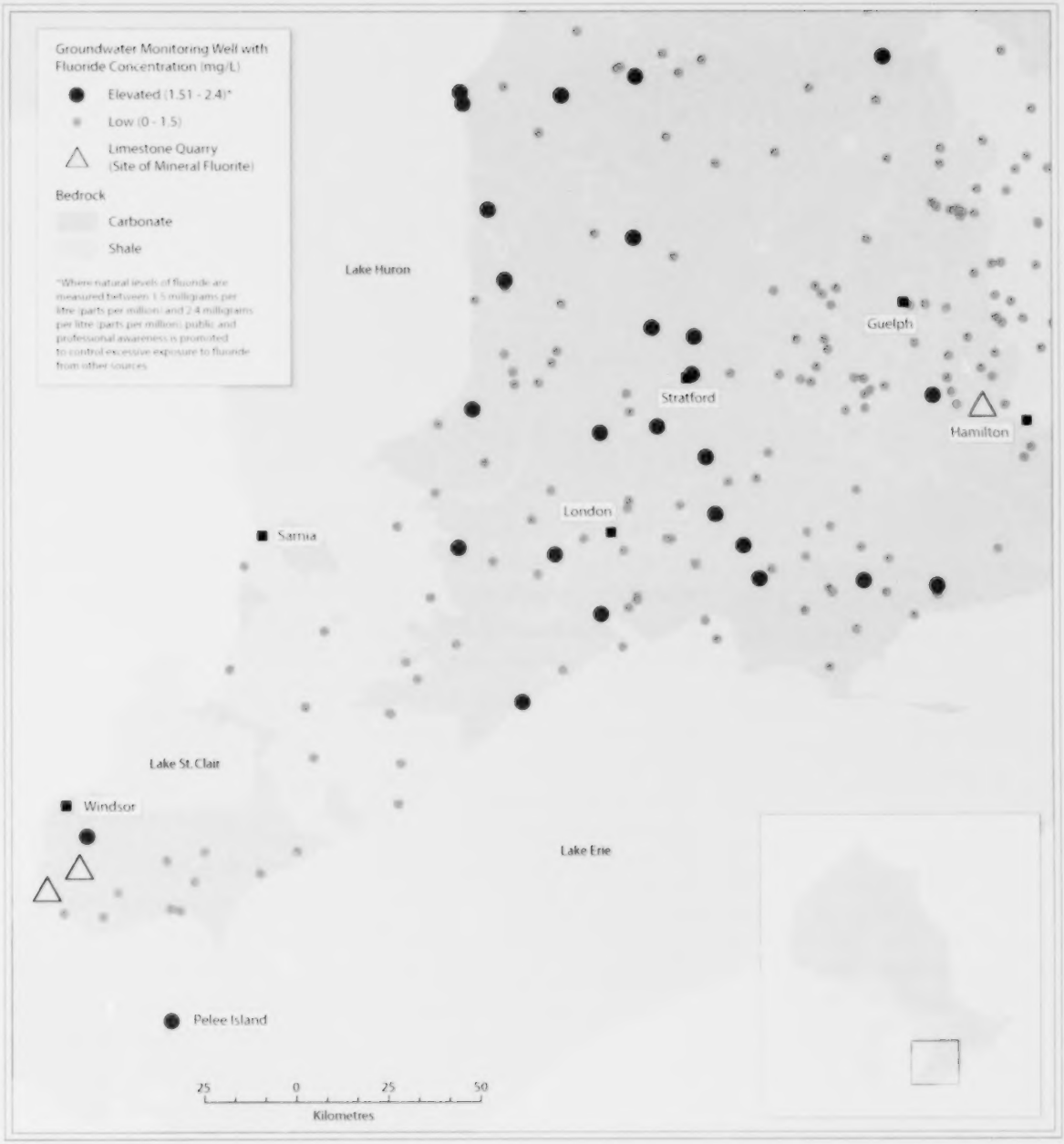

Groundwater Monitoring Well with Fluoride Concentration (mg/L)
Elevated (1.51 - 2.4)*
Low (0 - 1.5)
Limestone Quarry (Site of Mineral Fluorite)
Bedrock
Carbonate
Shale
*Where natural levels of fluoride are measured between 1.5 milligrams per litre (parts per million) and 2.4 milligrams per litre (parts per million), public and professional awareness is promoted to control excessive exposure to fluoride from other sources.
Lake Huron
Guelph
Stratford
Hamilton
London
Sarnia
Lake St. Clair
Windsor
Lake Erie
Pelee Island
25 0 25 50
Kilometres

Figure 5.5 Groundwater quality monitoring results from the ministry's monitoring programs show that fluoride concentrations are elevated in a number of wells in southwestern Ontario. An assessment report found that fluoride in groundwater is naturally-occurring and associated with carbonate bedrock.

in areas where the bedrock is a carbonate. The carbonate bedrock of limestone and dolostone was formed 300 to 500 million years ago. Southwestern Ontario was covered by a shallow tropical sea, which provided ideal conditions for the growth of coral reefs; over millions of years, the reef-building organisms built up a layer of carbonate rock that is over a kilometre thick.

Throughout the world, fluoride is found in groundwater in carbonate formations. In almost all cases, the source of the fluoride is from the mineral fluorite (calcium fluoride or CaF_2). This is found in limestone quarries in southwestern Ontario, such as the Dundas quarry near Hamilton and the Amherstsburg quarry near Windsor. These locations and others are shown as yellow triangles on the map in Figure 5.9.

The occurrence of fluorite has been studied in southwestern Ontario and in the States surrounding the Great Lakes. The studies found that fluorite was deposited by a warm mineral-rich fluid that traveled through pathways in the carbonate rock hundreds of millions of years ago. The pathways were created as a result of faults, fractures, and porous zones formed by the original reefs. The proximity of a groundwater monitoring well to a pathway may be a reason for the elevated levels of fluoride in the groundwater. Local chemical conditions of the groundwater may also play a role.

Fluoride concentrations in water samples are measured in the ministry's laboratory using ion chromatography mass spectrometry.

Elevated fluoride levels have been detected in the Gulf Islands of British Columbia and in the Gaspe Peninsula of Quebec. In these locations, it was found that a naturally occurring process called base-exchange softening was responsible for allowing fluoride to reach elevated concentrations. The process works the same way as a home water softener, causing the groundwater to become softer. If calcium was present, it would attach to the fluoride in the water and produce calcium fluoride or fluorite. Soft water does not have a lot of calcium in it; therefore fluoride can be found in elevated levels in the groundwater because it cannot attach to calcium and precipitate out as the mineral fluorite.

Another possible source of fluoride could be in the overburden – the sediment that lies on top of the bedrock. Most of the overburden of southwestern Ontario was formed by the glaciers that occupied the area up to 10,000 years ago. A large component of some of these sediments is clay, which has been associated with elevated fluoride levels.

Further analysis on the information collected by the ministry's groundwater monitoring programs is being conducted to see if these processes are contributing to elevated levels of fluoride.

6.0 Climate Change

What is climate change?

Since the start of the industrial revolution, humans have been adding large amounts of greenhouse gases to the atmosphere, mainly by burning fossil fuels such as coal, oil and natural gas. Greenhouse gases, such as carbon dioxide, methane and nitrous oxide, trap radiation from the sun in the lower part of the Earth's atmosphere. As the amount of greenhouse gases in the atmosphere increases, the amount of solar radiation that is trapped also increases, which raises temperatures. This is known as the *greenhouse effect* and the resulting increase in temperature is called *global warming*. When global warming affects weather patterns, it is referred to as *climate change*. Climate change is a long-term shift in the typical weather conditions at a given location. It is measured by temperature, amounts and intensity of precipitation (rain and snow) and wind patterns.

Will Ontario's environment be affected?

In Ontario, temperatures are predicted to increase by 3 to 8 °C over the next century. This could result in milder winters, longer growing seasons and increased frequency of severe weather events like storms (including freezing rain), floods, droughts and heat waves. These changes will have positive and negative effects on Ontario's environment and natural resources, human health and the economy.

The scope of this report does not encompass the full range of environmental effects associated with climate change. This report focuses on the effects of climate change on water quality in Ontario, including effects that are already measured by monitoring and those that are anticipated. For more information on the effects of climate change and *Ontario's Action Plan on Climate Change*, please visit (http://www.ene.gov.on.ca/en/air/climatechange/index.php). To learn what you can do to reduce greenhouse gas emissions please visit (http://addituponta rio.ca/index.html).

Effects of climate change on water quality in Ontario

Climate change is expected to have effects on aquatic ecosystems in Ontario. However, changes in water quality that will result from a warming climate are complex, and can be difficult to understand and predict.

Generally drier conditions, including increased periods of drought in some areas, are expected under a warming climate. Under warmer conditions, less precipitation is expected to fall as snow, which could result in reduced rates of groundwater recharge from melting snow. The elevation of the

groundwater table could drop in periods of drought or decreased recharge, reducing groundwater contributions (baseflow) to streams, which could lower the capacity of streams to assimilate runoff from the landscape and discharges from waste water treatment plants.

The timing and magnitude of rainfall and runoff and streamflow patterns is also expected to change, with associated effects on water quality. Rainstorms are expected to increase in intensity (more rain falling in a shorter period of time), which could result in increased erosion and flushing of contaminants from the landscape (including agricultural drains and urban storm water systems) into surface waters. If changes in patterns of runoff alter the exports of nutrients and other elements to lakes and streams, large effects on aquatic habitats and communities are likely.

In Ontario's lakes, longer ice-free seasons will result from climate warming because of later freezing and earlier thawing. Trends toward longer ice-free seasons have already been seen in the Northern Hemisphere. This could have both positive and negative effects on lake ecosystems. Longer ice-free seasons could spare fish from winter kills by shortening the duration of ice cover. However, it might increase the length of time that cold water fish must tolerate lower oxygen levels while they remain isolated in the hypolimnion (colder bottom waters) during extended periods of warmer weather (longer summers).

In lakes deep enough to develop strong vertical temperature gradients in summer, longer periods of such thermal stratification (formation of layers of different water temperature) are expected to result from climate warming. This may extend the periods during which species with different temperature requirements are separated by temperature conditions, and change their interactions.

Lake temperatures are affected directly by weather, but are also influenced by watershed processes that affect lake water clarity and light penetration. Most of Ontario's lakes are located in central or northern Ontario, and most are relatively small. In these lakes, the water clarity is usually determined by concentrations of dissolved organic carbon (DOC), produced by the decomposition of plant material in lakes and their watersheds.

The effects of weather on DOC will be varied and complicated. Shifts in vegetation types and changes in the rates of basic processes of organic matter breakdown may result in long-term, gradual change. Shorter-term factors such as severe droughts can reduce the supply of DOC to lakes from

Climate change is expected to have effects on aquatic ecosystems in Ontario.

their watersheds. While increased lake clarity has been observed during droughts, the general trend in Ontario lakes over the last three decades has been increased DOC concentrations and decreased clarity. If this trend continues, thinner, warmer surface layers and more cold water habitat in many lakes would be expected.

The biological responses to changed thermal habitats are expected to be very complex. Changed thermal habitats will favour some species and negatively affect others. Some native and introduced aquatic species will likely expand their ranges with climate warming, with negative consequences for resident species. For example, increased surface temperatures could result in northward expansions of warm water species such as smallmouth bass, with negative consequences for other species such as lake trout.

What is monitoring telling us?

The ministry's long-term monitoring programs are helping us understand and document the effects of climate change on aquatic ecosystems

throughout Ontario. This supports our ability to make realistic forecasts of the future effects of climate change on aquatic ecosystems and helps us make plans to protect water quality.

The effects of climate change on aquatic ecosystems are challenging to measure, especially in the developed regions of Ontario. Separating the effects of climate change (e.g., drought) from the effects of land use activities (e.g., water withdrawals) is difficult. This reinforces the value of the ministry's long-term monitoring programs in areas minimally impacted by human development. These programs are needed to identify impacts associated with climate change and to develop plans to adapt.

Many of the consequences of a changing climate are a result of indirect effects or impacts, which interact with other (multiple) stressors. For example, the types of algae in the lakes around the Dorset region of Ontario have changed dramatically since the ministry initiated monitoring in the mid-1970s. The monitoring results point to a changing nutrient supply, which is the result of previous acidification of watersheds (acid rain) and increased incidence of drought (climate change).

Periods of drought in regions with a history of excess sulphur deposition, including much of Ontario, can release sulphur that is stored in wetlands. When wet conditions resume, the previously stored sulphur can react and cause re-acidification and many related changes including increased water clarity and changes in thermal structure, as shown by monitoring data for Swan Lake in northern Ontario (Figure 6.1). These changes can have major impacts on lake communities, including phytoplankton, zooplankton and fish.

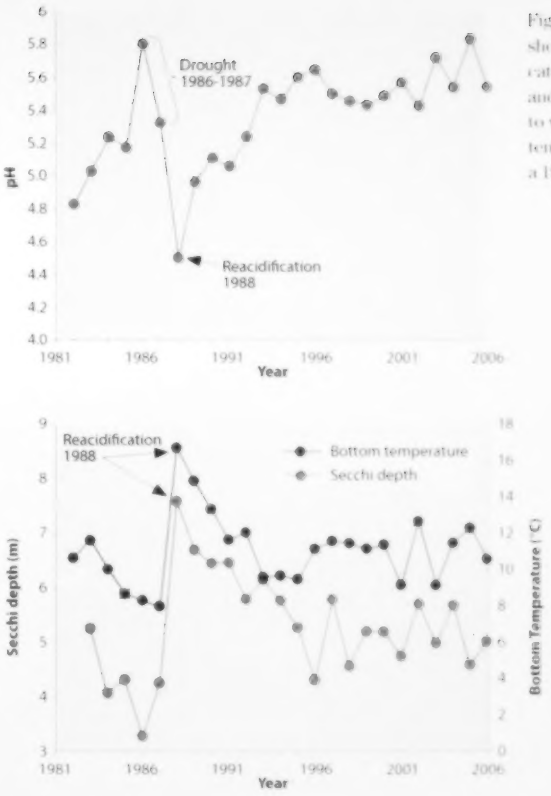


Figure 6.1 The graph shows the re-acidification of Swan Lake and related changes to water clarity and temperature following a 1986-1987 drought.

In general, acidified lakes are expected to become less clear as they recover from acidification, since DOC concentrations usually increase as acidity decreases. In areas with a history of acidification damage, such interactions will need to be considered in future estimates of the effects of climate change. For example, monitoring results for Whitepine Lake, northern Ontario, which is recovering from acidification, provide an example of long-term changes in, and interactions between, summer air temperature, pH, DOC and thermal characteristics (Figure 6.2). This lake has undergone significant changes in

thermal structure including trends toward a shallower surface layer and increased coldwater habitat as pH, DOC concentrations and air temperatures generally increased over the last two decades.

Our ability to forecast the nature and extent of likely effects of climate warming is restricted by our limited understanding of the direct and indirect interactions between weather, watersheds and lake habitats, and their effects on aquatic ecosystems. It is clear that the effects of climate change on lakes will interact with the effects of other large-scale environmental stressors such as acidification, urbanization and exotic species invasions. Therefore, the monitoring and assessment studies required to develop our understanding of the potential effects of climate change on aquatic ecosystems will have to be done within a multiple stressor framework.

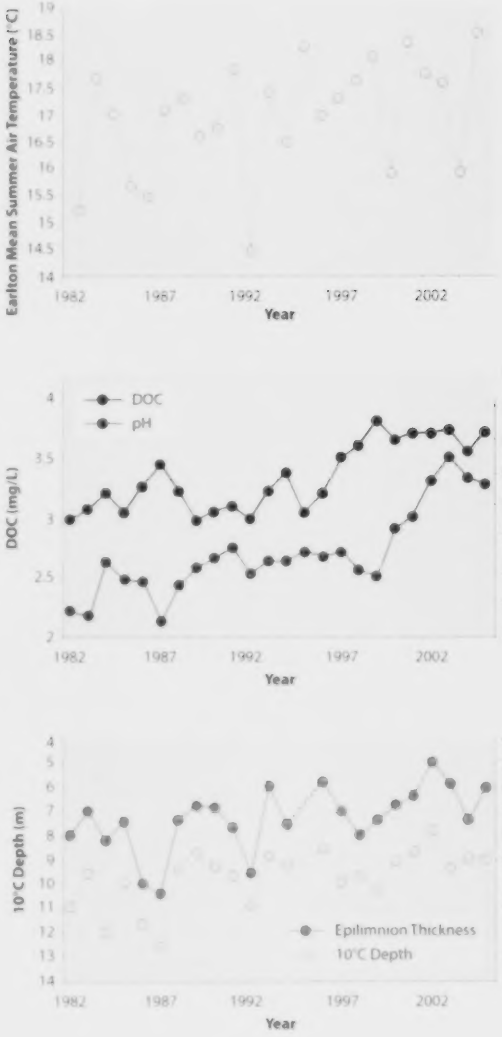


Figure 6.2 Patterns in:

(a) mean summer air temperature,

(b) DOC concentration and pH, and

(c) late-summer 10 °C depth and mixed layer (epilimnion) thickness, in Whitepine Lake, 80 km north of Sudbury.

6.1 Climate Change Affects Lake Ecosystems

Key Facts

Air temperatures in northwestern Ontario are the warmest they have been in more than a hundred years of instrumental record keeping.

In more southerly regions of the province, the effects of increasing air temperature on lake ecosystems may be blurred, as these areas are typically subjected to multiple stressors that can mask or override climatic signals.

However, in regions where levels of acid rain and shoreline development are minimal (e.g., remote areas of northwestern Ontario), the impacts of climate change on lake ecosystems are more clearly evident.

"Fossils" preserved in lake sediment cores from the Lake of the Woods and the Experimental Lakes Area in northwestern Ontario record significant changes in the biology of remote lakes since pre-industrial times (pre-1850), with marked changes occurring over the past three decades.

Biological changes in these lakes are closely related to changes in air temperature and ice dynamics (e.g., the duration of the ice-free period), providing evidence that these lakes have been affected by climate change.

A warmer climate

Air temperatures in temperate latitudes of North America have increased over the last century, with some of the highest rates of increase observed in northwestern Ontario. Temperature records from Kenora airport, measured since 1899, show a rise in annual air temperatures in recent decades, with an increase of more than 1°C since the early 1980s (Figure 6.3a). Warmer temperatures have resulted in a lengthening of the frost-free season by 13 days since the 1920s, and an increase in the ice-free period in Lake of the Woods by four weeks since the mid-1960s (Figure 6.3b).

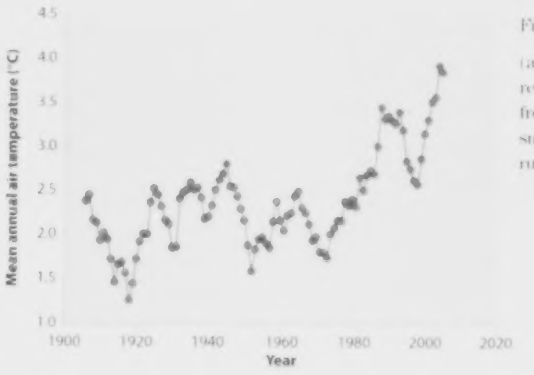
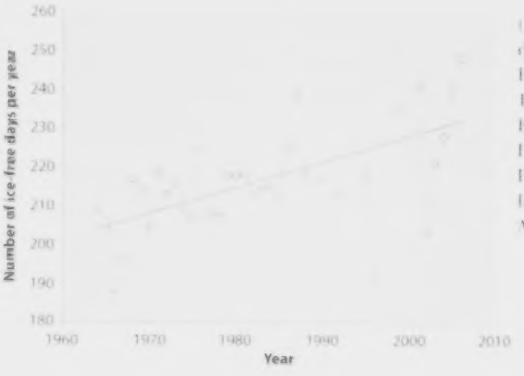


Figure 6.3

(a) Mean annual temperature recorded at Kenora airport from 1899 to 2005; data are smoothed using a 7-year running mean.



(b) The number of ice-free days recorded in Whitefish Bay, Lake of the Woods from 1964 to 2006. Data sources: Environment Canada Historical Adjusted Climate Database; Ministry of Natural Resources, Kenora Fisheries Assessment Unit.

Paleolimnology: Unlocking secrets of the past

Paleolimnology is the scientific study of lake history. Paleolimnologists extract and interpret the information contained in lake sediments. While significant long-term monitoring records exist for inland lakes in Ontario, these are too short in duration to interpret "natural" conditions before the onset of major disturbances such as acid rain. The science of paleolimnology can be used to extend existing monitoring records thus providing a long-term perspective on important environmental issues.

A wealth of information can be extracted from lake sediments. Diatoms, a diverse group of microscopic algae, are commonly found in sediment cores. These tiny organisms exist anywhere there is water. Their cell walls are made of highly-resistant glass, with every species having a unique pattern.

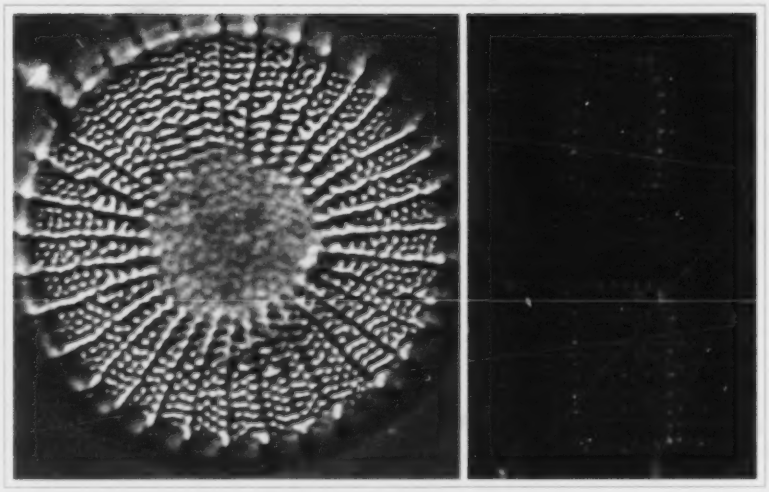
The survival of individual diatom species in lakes depends on physical properties such as light and water temperature, and water quality,

Air temperatures in temperate latitudes of **North America** have **increased** over the last century, with some of the **highest rates of increase** observed in **northwestern Ontario**.

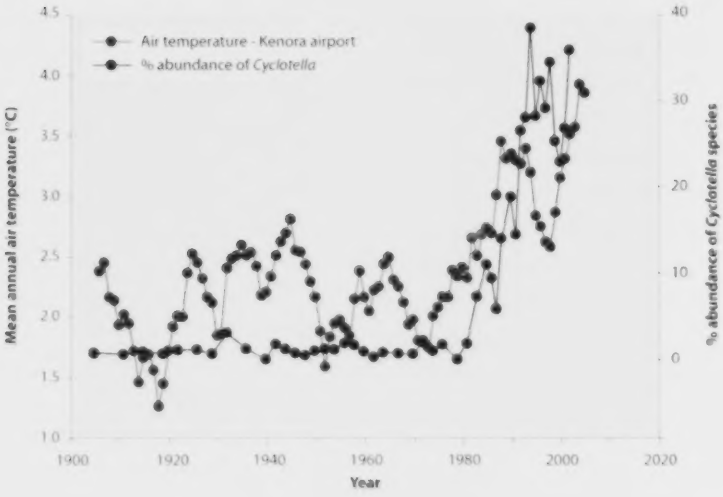
such as the availability of nutrients. These physical and chemical conditions in lakes may change over time in response to external factors like changing climate. For example, as air temperatures warm, the duration of the spring mixing period may shorten, the period of the open-water season may lengthen, and the duration and strength of thermal stratification may increase in lakes. These lake properties, in turn, may affect the availability of light in the water column, and the availability and distribution of nutrients that affect the growth of algae. Algae form the base of aquatic food webs and transfer energy and nutrients to aquatic animals including fish. Thus, changes to their abundance or composition as a result of climate change and other stressors may have cascading effects to higher levels of the food web.

Case Study: Diatom changes in Lake of the Woods

In partnership with researchers at Queen's University, changes in the diatom community preserved in a lake sediment core from Lake of the Woods were examined. Using radiometric dating techniques (similar to carbon dating), it was determined that the core was more than one hundred years old, allowing a direct comparison of the diatom record to the climate record from Kenora Airport. A marked shift was observed in the composition of diatom algae in the sediment core over time. An increase in the abundance of small diatoms of the fast-growing *Cyclotella* species was found. *Cyclotella* generally do well in years with longer



Magnified images of the siliceous cell walls of two diatom species (photos courtesy of Kathleen Rühland, Queen's University).



ice-free periods and/or a more stable water column. These conditions have been recorded in Lake of the Woods over the past two decades as a result of warmer air temperatures. Consequently, a significant correlation was found between biological changes and changes in air temperature (Figure 6.4) and the duration of the ice-free period.

Lakes across the globe are responding to changes in climate. Biological changes similar to the ones reported here are evident in lakes across vast regions of the Northern Hemisphere, with striking similarities in the nature of the diatom trend. The changes are widespread, and have occurred with increases in mean temperatures that are substantially lower than levels projected by climate models.

Figure 6.4 Comparison of the relative abundance of *Cyclotella* diatom species and air temperature recorded at Kenora Airport in northwestern Ontario. These records are significantly correlated over time. Modified from Rühland et al. 2008. Hemispheric-scale patterns of climate-related shifts in planktonic diatoms from North American and European lakes. Global Change Biology. In Press.

7.0 Summary and Conclusions

Water quality improvement strategies have been **successful**, but **continued vigilance is needed** to restore and protect water quality in Ontario.

The scope of the information collected by the Ministry's water quality monitoring programs is too broad for all of the findings to be summarized in a single report. Rather, this report presents selected findings from the Ministry's programs that are relevant to current water quality issues in Ontario including: phosphorus enrichment; toxic substances; acid deposition; and the growing issue of climate change.

The monitoring results presented in this report show that water quality improvement strategies have been successful, but that continued vigilance is needed to restore and protect water quality in Ontario.

Phosphorus levels in the Great Lakes and many streams and inland lakes have declined in response to management actions including reductions in phosphates in laundry detergents, improvements in waste water treatment, and the implementation of best management practices in urban and agricultural landscapes. Phosphorus concentrations have also declined in lakes in undeveloped watersheds on the Canadian Shield, possibly due to acid deposition and climate change. This is one of many examples where multiple stressors are interacting to influence water quality.

The effects of climate change on aquatic ecosystems can be challenging to measure in environments where there are multiple stressors. However, there are clear indications that a warming climate is already affecting Ontario's water resources. Monitoring is showing that changes in algal communities in northern Ontario lakes are related to warming air temperatures and longer ice-free seasons. The effects of climate change will interact with the effects of other environmental stressors such as acid deposition, land use activities (e.g., urban development) and the invasion of exotic species. Monitoring provides important information for helping us manage water resources in the face of this complexity. Monitoring also tracks the results that have been achieved in restoring and protecting water quality.

Successful efforts to reduce phosphorus loads to the Great Lakes over the last three decades appeared to be

alleviating the problem of shoreline fouling by the green alga *Cladophora*. However, *Cladophora*-related complaints are increasing. A possible explanation is that phosphorus levels are increasing on a local scale along some areas of shoreline and contributing to the enhanced growth of algae. Phosphorus levels in many rivers and streams, including some tributaries to the Great Lakes, continue to exceed water quality objectives for the prevention of nuisance plant growth and algal blooms. Other explanations for the resurgence in *Cladophora* focus on impacts of invasive mussels, which could be helping to create more favourable conditions for *Cladophora* growth.

The damaging effects of acid deposition have been reduced, leading to the recovery of many lakes in central and northern Ontario. Dramatic improvements in water quality have been seen in some lakes in the Sudbury region following reductions in acid-causing emissions from metal smelters. There is also evidence that aquatic animal communities are recovering. Despite these encouraging signs, uncertainty remains with respect to acid deposition. Some Ontario lakes are still affected by ongoing acid deposition, and many are still in the process of recovery. Furthermore, declines in lake sulphate have not been as great as expected given the large decreases in acid deposition that have been measured. Possible explanations include reductions in the amount of acid-neutralizing calcium in watersheds following decades of acid deposition and releases of sulphur stored in wetlands with periods of drought, which is likely related to a warming climate.

Government regulations to ban some chemicals and limit the amounts of chemicals that can be released in industrial discharges have dramatically reduced the amounts of these targeted substances in the environment. Concentrations of toxic substances, including PCBs and mercury, are decreasing in sport fish from the Canadian Great Lakes and Ontario's inland lakes. However, sport fish consumption advisories are still required for many lakes and streams in Ontario due to ongoing contamination of fish by toxic substances. Some substances persist in the environment due to their stable nature, and the difficulty and cost of cleaning up contaminated areas. Some new chemicals used in consumer and building products have been found in increasing concentrations in the environment. The Ministry of the Environment is committed to its monitoring programs to provide valuable information for protecting water quality in the future as new issues emerge.

8.0 Appendix A: Monitoring Program Descriptions

8.1 Great Lakes Monitoring

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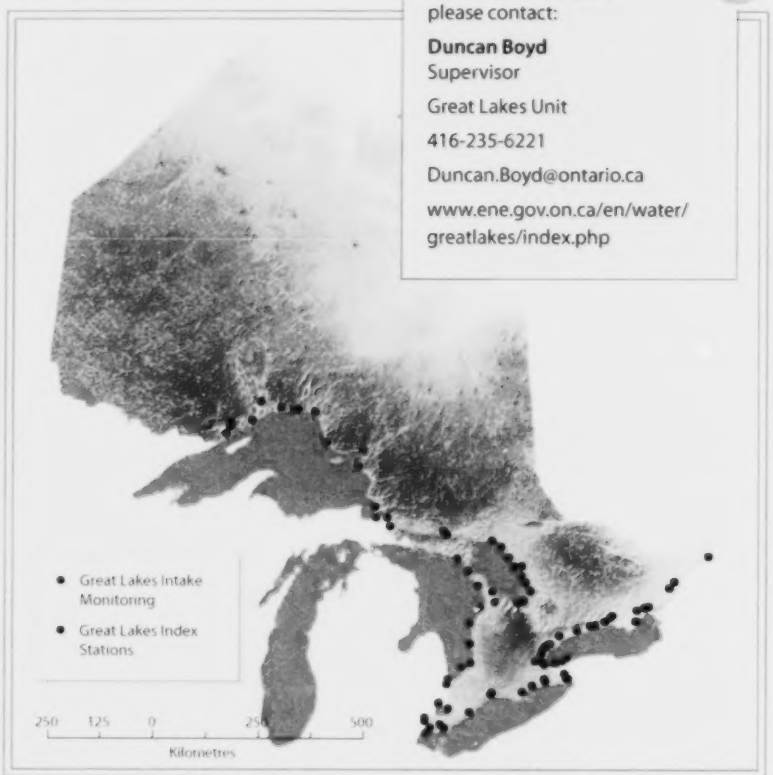

Great Lakes Index Station Network

The Great Lakes Index Station Network is designed to provide information on where and how water quality conditions are changing over time by periodically monitoring a comprehensive suite of environmental indicators (sediment, plankton, benthic invertebrates, water chemistry). Approximately 60 sites have been established throughout the Great Lakes basin. Sites are sampled on a lake-by-lake basis over a multi-year cycle.

Great Lakes Reconnaissance and Mapping Surveys

The Great Lakes Reconnaissance and Mapping Surveys measure a suite of environmental indicators in the nearshore – the area of the lakes that is most strongly and directly affected by land uses. Spatial patterns in water quality are mapped along selected ranges of shoreline throughout the Great Lakes. Surveys are undertaken in the spring, summer and fall, and combine high-resolution mapping of water quality indicators using high tech sensors with ground-truth sample collection.

Great Lakes Toxics Biomonitoring

Long-term monitoring of contaminant levels in mussels, zebra mussels, juvenile fish, and selected sport fish is undertaken to track levels of toxic contaminants through time across the Great Lakes. A basic network of approximately 50 sampling zones has been established throughout the Great Lakes for juvenile fish monitoring with approximately 35 sampled in any given year. In addition, an ongoing network of stations has been established in the Niagara River for mussel biomonitoring.

Great Lakes Water Intake Monitoring

The Great Lakes Water Intake Monitoring program measures trends in nutrient status using nutrient concentrations and phytoplankton biomass as indicators. Samples are collected year round at the intakes of 17 water treatment plants drawing water from the Great Lakes.

Investigative Monitoring

Investigative monitoring consists of surveys that are specifically designed to examine site-specific environmental impacts of known contaminant sources.

8.2 Inland Lake Monitoring

Lake Partner Program

The Lake Partner Program provides nutrient (total phosphorus) and water clarity information for Ontario's inland lakes. More than 600 lakes are monitored annually with the support of volunteers. The program began in 1996 in partnership with the Federation of Ontario Cottagers' Associations and the Lake of the Woods District Property Owners' Association. The program grew out of the Self Help program which had been collecting chlorophyll and water clarity information since the early 1970's. A Lake Partner summary report is published annually to share information on the nutrient status and water clarity of Ontario lakes.

Long-Term Monitoring of Dorset Area Lakes

The monitoring focuses on eight small lakes and associated inflowing and out-flowing streams that are located near Dorset, in south-central Ontario, which are representative of the tens of thousands of small, sensitive lakes on the Canadian Shield. Monitoring water quality and quantity, and phytoplankton and zooplankton communities began in the mid 1970's. Benthic invertebrate data collection was added in the late 1980's. Partnerships in data collection and analysis, which began in 2000 with Trent University and York University, have expanded to include researchers from numerous government agencies and universities. Additional lakes are sampled on a periodic basis to supplement information collected on the core eight lakes. Data are used to develop long-term trend information on lake and stream health with respect to recovery from acid deposition, mercury impacts, changes in nutrient status, and the impacts of climate change and introduced species.

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Long-Term Monitoring of Sudbury Area Lakes

The Ministry has been monitoring the Sudbury area since the 1970's to understand the functioning of aquatic ecosystems damaged by industrial pollution, to assess and monitor the process of recovery and rehabilitation of these ecosystems, and to develop and test rehabilitation techniques that speed up the recovery process. Monitoring has been conducted by the Cooperative Freshwater Ecology Unit (Co-op Unit), a partnership between MOE, MNR and Laurentian University, with the support of a number of partners including Vale Inco, Xstrata Nickel, Environment Canada, and the City of Greater Sudbury, since 1989. The Co-op Unit attracts academic collaborators worldwide.

Recently, the focus of the research conducted has shifted to include climate change and multiple stressor research. Monitoring focuses on 54 lakes in the Greater Sudbury Area, but periodically includes other lakes in northern Ontario, and applies to other areas on the Canadian Shield and globally that are affected by industrial acid gas emissions. Results of the monitoring and related investigations are presented at the biennial Sudbury Restoration Workshop and other scientific conferences, published in scientific papers and technical reports, and presented in summary form to the public in information brochures.

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8.3 Stream Monitoring

Provincial (Stream) Water Quality Monitoring Network

The Provincial (Stream) Water Quality Monitoring Network measures water quality in rivers and streams across Ontario. Over 400 locations are currently monitored in partnership with Ontario's Conservation Authorities, participating municipalities and provincial parks. Partners collect water samples on an approximately monthly basis and deliver them to the Ministry's laboratory where they are analyzed for a suite of water quality parameters. Water quality data are shared freely between the partners and with the public. The program has been operating since 1964 providing a valuable database for tracking changes in water quality over time. More recently, special studies have been implemented in agricultural and urban watersheds to collect additional information in support of source protection planning and nutrient, road salts and pesticides management.

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8.4 Groundwater Monitoring

Provincial Groundwater Monitoring Network

The Provincial Groundwater Monitoring Network (PGMN) measures groundwater levels and chemistry across Ontario. The program was initiated in 2000 and is implemented in partnership with Conservation Authorities and municipalities. Over 460 well sites are currently monitored. The program uses innovative technologies to transmit real-time groundwater level and precipitation information from well sites to a web-based information system. Groundwater levels are measured once per hour and groundwater chemistry is analyzed once per year. Data are stored in the program information system and made accessible to program partners. Local Health Units are notified when an Ontario Drinking Water Quality Standard for a health-related parameter is exceeded. Rain gauges are currently being installed at selected well sites to integrate weather and groundwater information. Special studies and projects are being undertaken to address provincial issues and support Ministry activities.

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8.5 Drinking Water Monitoring

Drinking Water Surveillance Program

The Drinking Water Surveillance Program was developed in 1986 in cooperation with participating municipalities to gather scientific data on drinking water quality in Ontario, with a particular focus on non-regulated drinking water quality parameters and emerging contaminants such as pharmaceuticals. The program complements both the Ministry's audit inspections and compliance monitoring carried out by drinking water systems. The drinking water systems that are monitored in the program represent approximately 80% of Ontario's population that is served by municipal drinking water. Since 1986, the program has collected over 4.5 million results at nearly 1500 sample point locations for raw water, treated drinking water, and water in the distribution system.

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www.ene.gov.on.ca/publications/7018e.pdf

8.6 Biomonitoring

Ontario Benthos Biomonitoring Network

The Ontario Benthos Biomonitoring Network (OBBN) measures aquatic ecosystem condition in lakes, streams and wetlands using bottom-dwelling aquatic invertebrates as indicators. The program was initiated in 2003 and over 700 sites have been monitored across Ontario. The program specifies standard biomonitoring methods for Ontario, provides training and certification for its members, and allows data to be shared via an internet database. The program is guided by a technical committee comprising government, academic, and Conservation Authority representatives. All sectors are represented among the program's members including Conservation Authorities, provincial and national parks, universities and colleges, businesses, municipalities, community groups, and citizen-scientist volunteers. These members contribute and share sampling data collected at hundreds of sites each year. Some members collaborate in scientific research that will improve our understanding of aquatic ecosystems.

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Northern Ontario Benthic Invertebrate Reference Condition Approach Biomonitoring Network

The Northern Ontario Benthic Invertebrate Reference Condition Approach Biomonitoring Network is defining the normal range in benthic invertebrate communities in lakes and streams of Northern Ontario. The network was created in 2003 as a collaboration between the federal and provincial governments, industry and academia to assist regulators and the metal mining industry in the assessment of mining effects on surface waters. Both reference (unimpacted) and impacted (discharge sites, historical mine impact and urban impacts) sites are being studied. Over 300 sites, some of which are being followed every year, have been sampled in the vicinity of four northern mining areas (Sudbury, Hemlo, Red Lake, and Timmins). Modeling of the benthic community data from reference sites is being used to predict natural communities expected at impacted sites. Data are being shared via an online database among partners (e.g. OBBN) and outside collaborators to answer science questions. Various other impacts could be assessed using the network data including other industrial discharges, climate change, hydro-electric impounding, sewage discharges, urbanization and road construction.

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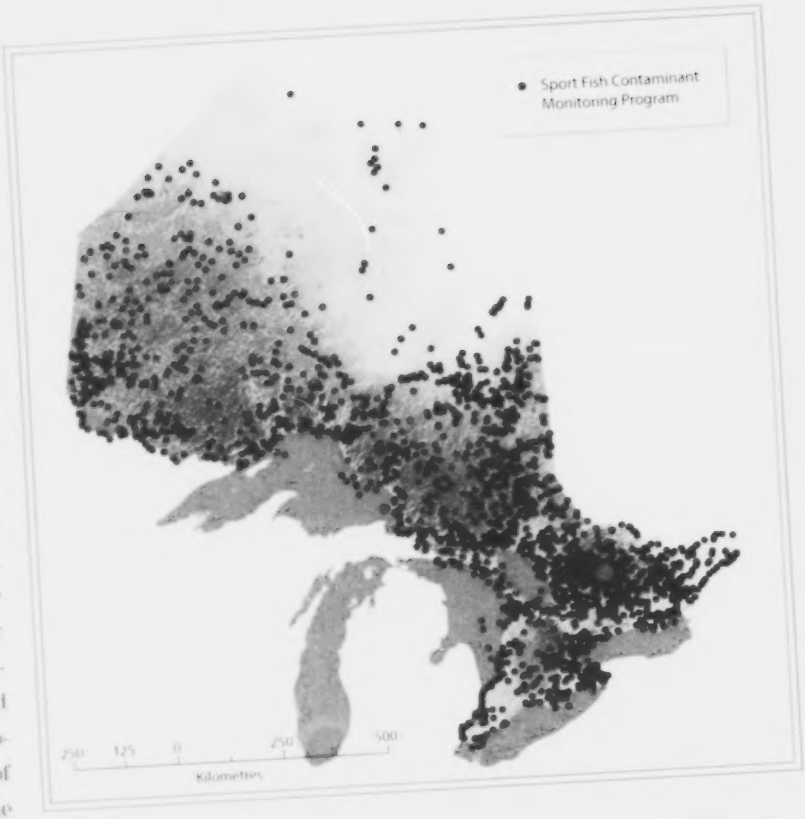
Sport Fish and Juvenile Fish Contaminant Monitoring Program

The Sport Fish Contaminant Monitoring Program provides advice to the public on safe levels of sport fish consumption through the biennial publication of the *Guide to Eating Ontario Sport Fish*. Sport fish monitoring in Ontario began in 1970, while the program officially started in 1976 with the first *Guide* published in 1977. The 2009-2010 edition of the *Guide* provides fish consumption advice for 1860 locations in the province. Approximately 6000 sport fish are collected annually and analyzed for a variety of contaminants. Consumption advisories are calculated based on health protection guidelines provided by Health Canada. Copies of the *Guide* are distributed across the province through government offices as well as various bait shops. An electronic copy of the *Guide* is available at (www.ontario.ca/fishguide).

In addition to sport fish contaminant monitoring, juvenile fish monitoring provides a means of identifying contaminant sources. Juvenile fish monitoring started in 1975 to monitor contaminant levels in the Great Lakes and selected inland lakes and rivers. The data have been published in scientific papers, ministry reports and technical memos. The data are also used by Conservation Authorities and other agencies in watershed report cards, State of the Great Lakes Reports, and Remedial Action Plan (RAP) reports.



For more information please contact:

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9.0 Appendix B: A Primer on Selected Toxic Substances

Mercury

Mercury is a metal that occurs naturally in the environment. It has been widely used in consumer and industrial products including electrical switches, thermostats and thermometers fluorescent lamps and batteries. Governments and industry have been taking action since the 1960s to reduce the use of mercury, and direct discharges of mercury to the environment have been virtually eliminated. However, significant quantities of mercury still enter the environment from both natural and human sources. Mercury can move between air, water and soil and can be transported long distances in the atmosphere. In the aquatic environment, mercury is attracted to sediment particles and settles to the bottom of surface waters where it enters the food chain. Mercury can build up in the tissues of aquatic animals, including fish, and can accumulate to levels that are harmful to consumers at the top of the food web, including humans. Most of the sport fish consumption advisories in Ontario's inland lakes are the result of mercury. Mercury is a neurotoxin and can cause damage to the brain, central nervous system and kidneys.

PCBs

Polychlorinated biphenyls (PCBs) are a group of chemicals that were in widespread use from the late 1920s to the late 1970s as coolants and lubricants for electrical equipment (e.g., transformers) because of their chemically stable nature. PCBs do not occur naturally in the environment so their presence is always associated with human activity. PCBs last for many years in the environment; they do not break down easily and they are difficult to destroy. There are several environmental and human health concerns associated with PCBs, and as a result, PCBs were banned from import, manufacture and sale in Canada in 1977. In 1985, PCBs were banned from release to the environment. Although there have been restrictions on the use of PCBs for 30 years, they are still present in our environment. Some old waste sites which were in-use before PCB regulations continue to slowly release PCBs to lakes and streams. Also, sediment at the bottom of many water bodies contains PCBs from both past and present contamination, so any movement or re-exposure of this contaminated sediment may also be a source of PCBs in the environment.

Dioxins, furans and dioxin-like PCBs

Dioxins (polychlorinated dibenzodioxins) and furans (polychlorinated dibenzofurans) are a group of chemical compounds created as unwanted byproducts in the manufacturing of other chemicals such as disinfectants, wood preservatives and herbicides. They are also produced during combustion including natural (e.g., forest fires) and human (e.g., waste incineration) sources. Like PCBs, dioxins and furans are fat soluble and can accumulate in the fatty tissues of animals and humans, mainly through diet. Dioxins and furans can result in a range of health effects depending on the level and duration of exposure. There are many different forms of dioxins and furans, which vary in their toxicity. Some forms of PCBs, called dioxin-like PCBs, have properties that are similar to toxic forms of dioxins. The Ministry monitors the toxic forms of dioxins, furans and dioxin-like PCBs. A majority of the consumption restrictions for sport fish in the Great Lakes and connecting channels are the result of dioxin-like PCBs, dioxins and furans.

Flame Retardants (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are human-made chemicals that have been added to consumer products, ranging from furniture and textiles to electronics, to make them less likely to catch fire. PBDEs are gradually released from these products when they are being manufactured, while they are in use and after they are discarded. PBDEs are often grouped in the category of "emerging chemicals" due to improved methods of detecting these substances in the environment and increasing levels of interest from scientists and the public. Some forms of PBDEs have now been phased out of use in several jurisdictions, including Canada, due to their accumulation in the environment and potential health concerns.

Pesticides (specifically DDT)

Pesticides are chemical compounds used to control unwanted pests such as weeds and insects. The use of the pesticide dichloro-diphenyl-trichloroethane (DDT) in Canada started in the 1940s to control insect pests in agricultural crops and for other domestic applications such as mosquito control. Like other persistent substances (e.g., PCBs), DDT can last a long time in the environment and can be transported long distances. It can also accumulate in the food web causing harm to top predators. The use of DDT was phased out in Canada in the 1970s following the discovery of its impacts. However, it is still used in some parts of the world to control the spread of disease by mosquitoes.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are a class of organic (carbon-based) chemical compounds produced as a result of incomplete combustion. They are released to the environment from natural (e.g., forest fires) and human sources (e.g., burning of fossil fuels and wood, metal smelting, waste incineration). Most PAHs have no known uses. However, a few are used to make products such as mothballs and creosote (from coal tar) wood preservatives. PAHs have low solubility in water and tend to adsorb to sediments where they persist. PAHs differ from chlorinated substances such as PCBs and DDT in that most organisms can metabolize them. However, they are persistent, and can accumulate in tissues resulting in toxic effects, including cancer.

10.0 Appendix C: Sources for Maps

Figure 1.1

Base Data: Ontario Land Cover Data Base

Projection: Lambert Conformal Conic

Datum: NAD 83 CNT

Figure 1.2

Thematic data: Ministry of Northern Development and Mines (MNDM)

Projection: Lambert Conformal Conic

Datum: NAD 83 CNT

Figure 3.4

Base Data: Ministry of Natural Resources (MNR) NRVIS (Natural Resources & Values Information System)

Projection: Lambert Conformal Conic

Datum: NAD 83 CNT

Figure 3.7

Base Data: MNR NRVIS

Projection: UTM Zone 17

Datum: NAD 83 CNT

Figure 3.11

Thematic Data: Environmental Monitoring and Reporting Branch (EMRB), Ministry of the Environment (MOE)

Base Data: MNR NRVIS

Projection: UTM Zone 17

Datum: NAD 83 CNT

Figure 3.12

Thematic Data: EMRB, MOE

Base Data: MNR NRVIS

Projection: UTM Zone 17

Datum: NAD 83 CNT

Figure 3.13

Thematic Data: EMRB, MOE

Base Data: MNR NRVIS

Projection: UTM Zone 17

Datum: NAD 83 CNT

Figure 4.1

Thematic Data: EMRB, MOE

Base Data: MNR NRVIS

Projection: UTM Zone 17

Datum: NAD 83 CNT

Figure 5.3

Base Data: MNR NRVIS

Projection UTM Zone 17

Datum: NAD 83 CNT

Figure 5.5

Thematic Data: EMRB, MOE

Base Data: MNR NRVIS; MNDM

Projection: UTM Zone 17

Datum: NAD 83 CNT

Appendix Maps

Thematic Data: EMRB, MOE

Base Data: MNR NRVIS

Projection: Lambert Conformal Conic

Datum: NAD 83 CNT

11.0 Glossary

Acid-damaged: A water body that has been impacted by acid deposition, typically associated with reductions in the numbers and types of aquatic species.

Acidification: A process that increases the acidity (lowers the pH) of a water body.

Algae: A group of aquatic organisms with all or most of the following features: they photosynthesize; they have simple vegetative structures without a vascular system; and they have reproductive bodies that lack a sterile layer of protecting cells.

Ambient: Natural or background conditions in the environment away from areas where water quality is influenced by a specific discharge or source of contamination.

Aquatic: Pertaining to water.

Aquifer: A layer of soil, sand, gravel or rock that contains groundwater.

Area of Concern: An area within the Great Lakes Basin where water quality problems have been identified.

Assimilative capacity: The ability of a water body to dilute or transform treated waste water such that impacts on aquatic ecosystems and human uses of water resources are minimized.

Attached algae: Algae that grow on submerged surfaces. See also Algae.

Background: Water quality conditions upstream of a source of pollution.

Banned chemical: A substance that is restricted in use, manufacture, transport and sale by government regulations.

Bedrock: Consolidated (solid) rock exposed at the surface of the earth or underlying soils and other unconsolidated materials.

Benthic invertebrates: Insects, worms, crustaceans and other organisms without a backbone that live in, on, or near the bottom of water bodies.

Benthos: Synonymous with benthic invertebrates. See also Benthic invertebrates.

Bioaccumulative: A substance with the potential to build up (accumulate) in an organism to concentrations higher than the surrounding environment.

Bioavailable: A substance that can be taken up by an organism by ingestion or physical contact.

Caged mussels: Mussels that have been collected from an unpolluted water body and placed in cages at test locations to study the uptake of bioaccumulative substances.

Carbonate: Rocks (such as limestone and dolostone) that are made up of minerals containing the carbonate ion (CO_3^{2-})

Coldwater (habitat): Areas within a surface water body where the water temperature is cold enough to support species (such as trout) that require cold water.

Community (aquatic): All of the species that interact in a water body.

Concentration: Amount of a substance in a given volume of sample. In water, concentration is usually expressed as milligrams per litre (parts per million), micrograms per litre (parts per billion) and nanograms per litre (parts per trillion).

Contaminant: A substance that impairs water quality when released to the environment.

Contamination: Degradation of water quality compared to natural or original conditions caused by the release of contaminants. See also Contaminant.

Core: See Sediment Core.

Cyclotella: Microscopic, drum-shaped diatoms.

Dichloro-diphenyl-trichloroethane (DDT): A pesticide used to control insect populations. See Appendix B for more information.

Dioxins and furans: Dioxins (polychlorinated dibenzodioxins) and furans (polychlorinated dibenzofurans) are a group of chemical compounds created as unwanted byproducts in the manufacturing of other chemicals. See Appendix B for more information.

Discharge: A volume of water that flows past a given location in a given time interval. In streams, discharge is usually expressed in cubic metres per second.

Dissolved organic carbon (DOC): Microscopic pieces of organic (carbon-containing) matter in water.

Dissolved oxygen: Oxygen dissolved in water.

DOC: See Dissolved Organic Carbon.

Drought: A period of less than normal precipitation.

Ecosystem: A community of organisms and the environment in which they live.

Emerging chemical: A substance of increasing interest to scientists and the public.

Emission: The release of a substance into the environment.

Erosion: The process by which rocks and soils are worn away and moved from one place to another.

Exotic (species): A non-native organism.

Exposure: The process by which an organism comes into contact with a substance by direct physical contact or ingestion.

Fluorosis: Discolouration or pitting of the teeth resulting from excessive intake of fluoride. Also called dental fluorosis.

Food web: The interconnected feeding relationships in an ecosystem.

Geology: The study of the solid matter of the Earth (rocks, soils) and the physical processes that shape it.

Groundwater: Water that occurs beneath the surface of the Earth in saturated soils and geologic formations.

Guideline: Numerical concentration or narrative statement recommended to support a designated water use or to protect aquatic species.

Habitat: The area or part of the environment where an organism lives.

Hydrology: The study of the properties, distribution and movement of water.

Ice-free: The period of time when a water body is not covered with ice.

Inland: Away from large bodies of water (e.g. the Great Lakes) surrounded by land.

Intake: The location where water is withdrawn from a lake or stream for domestic purposes.

Intensity (precipitation): The rate of precipitation usually expressed as amount per unit of time.

Littoral zone: An area of a water body bounded by the shoreline and the limit of submerged aquatic plant growth.

Load: The amount of a substance entering a water body over a given time interval.

Major ions: Common constituents of water that occur naturally due to weathering of rocks and atmospheric deposition. Ions have a positive (cation) or negative charge (anion). Major cations include calcium, magnesium, sodium and potassium. Major anions include sulphate, chloride, fluoride and nitrate.

Mean: Average (the sum of the values divided by the number of values).

Minister: In this report, refers to the Ontario Minister of the Environment.

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Multiple stressors: Two or more stressors that have interactive and cumulative impacts on aquatic ecosystems (e.g. acid rain and climate change).

Neurotoxin: A toxin that adversely affects the central nervous system.

Nutrient: A substance that is necessary for the growth and survival of an organism.

Ontario Drinking Water Quality Standard: Maximum acceptable concentrations of a given water quality parameter as prescribed in O.Reg. 169/03 under the Safe Drinking Water Act, 2002.

Parameter: A measurable characteristic or feature of water quality.

Persistent: Substances that are not easily broken down and remain in the environment for long periods of time.

Pesticide: A chemical or mixture of chemicals used to kill unwanted species of plants and animals.

Photosynthesis: The process by which green plants use light energy to convert water and carbon dioxide into carbohydrates and oxygen.

Phytoplankton: Small, usually microscopic, aquatic plants. See also Zooplankton.

Plankton: See Phytoplankton and Zooplankton.

Pollutant: Any substance that, when released to the environment, degrades the environment such that living organisms can be harmed or human uses of natural resources are impaired.

Pollution: The release of pollutants to the environment. See also Pollutant.

Polybrominated diphenyl ethers (PBDEs): Human-made chemicals used as flame retardants in consumer products. See Appendix B for more information.

Polychlorinated biphenyls (PCBs): Human-made chemicals used as coolants and lubricants. See Appendix B for more information.

Population: Organisms of the same species that occupy a given area.

Precipitation: All forms of water, liquid (rain) and solid (snow, hail), that falls from the atmosphere to the surface of the Earth.

Provincial Water Quality Objective: Numerical and narrative criteria that are protective of all forms of aquatic life.

Quagga mussel: A non-native mussel (Dreissena rostriformis bugensis) that has been introduced to lakes and streams in North America including the Great Lakes and many of Ontario's inland lakes.

Remedial Action Plan: A strategy developed to restore and protect an Area of Concern in the Great Lakes.

Remediation: Taking action to reduce, isolate or remove contamination from the environment.

Runoff: Water from melting snow and rain that moves from the landscape into receiving water bodies.

Sediment: Particles, derived from rocks, soils and organic materials, which are suspended in, or deposited at the bottom of, a water body.

Sediment core: A long, cylindrical sample of sediment from the bottom of a water body collected using a hollow tube.

Sedimentary rock: Rocks that are formed by the consolidation of sediment.

Semi-Permeable Membrane Device (SPMD): An artificial device consisting of a plastic tube containing a lipid that accumulates contaminants when deployed in water.

Sensitive species: An organism that is particularly vulnerable to harm with degraded water quality or changes in the environment.

Sewage treatment plant: A facility designed to receive and treat waste water from domestic sources.

Smelter: A facility that extracts metal from ore.

Source: A place or object from which pollutants are released (pollution source). Also used to describe surface water bodies and groundwater aquifers that have the potential to supply a drinking water system (drinking water source).

Spill: The release of a pollutant of abnormal quality or quantity into the environment from a container.

Stratification: See Thermal stratification.

Stressor: An event or factor that adversely affects the well-being of an organism.

Surface water: Water on the Earth's surface including lakes, streams and wetlands.

Thermal stratification: The formation of layers of different water temperature and density in a lake.

Toxicity: The extent to which a substance can have harmful effects on organisms.

Toxin: A substance that can have harmful effects on organisms.

Tributary: A stream that flows into a larger stream or a lake.

Ultraviolet (UV) radiation: Invisible light from the sun with wavelengths between X-rays and visible light.

Watershed: An area of land from which water drains to a given point. Synonymous with drainage area, basin and catchment.

Weathering: The processes by which rocks are broken down.

Young-of-the-year (fish): Juvenile fish that are less than one year old; often used for monitoring in the proximity contaminant sources because the exposure period is known and their geographical range is limited.

Zebra mussel: A non-native mussel (Dreissena polymorpha) that has been introduced to lakes and streams in North America including the Great Lakes and many of Ontario's inland lakes.

Zooplankton: Small, usually microscopic, aquatic animals. See also Phytoplankton.

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